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Evaluation of Powdered Activated Carbon for Removal of Trace Organics at New Orleans, Louisiana

Roy F. Weston, Inc.
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This research effort studied the effect of powdered activted carbon on the removal of trace organics in the water treatment process at New Orleans, LA. The water treatment processes were modeled in bench scale reactors that allowed control of treatment variables. A series of experiments was conducted that incorporated the same treatment parameters as the full scale plant. Three powdered activated carbon dosages of 5, 50, and 500 mg/L were added at different locations in the bench scale treatment scheme and the results were compared to no PAC treatment. The results of the study showed that a dosage of 5 mg/L did not improve the removal of trace organics over the normal full scale treatment system. Only the 500 mg/L dosage performed well enough to achieve the promulgated standard of not more than 0.1 mg/L trihalomethane remaining in the finished water.

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EVALUATION OF POWDERED ACTIVATED CARBON FOR REMOVAL OF TRACE ORGANICS AT NEW ORLEANS, LOUISIANA

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This research program was initiated with the overall objective of determining the effect of powdered activated carbon on the removal of trace organics in the water treatment process. The water treatment processes were modeled in specially designed bench scale reactors which allowed control of treatment variables. The results of this project indicated that reasonable mg/L dosages of powdered activated carbon (PAC) (<50) did not improve the removal of trace organics over the normal full scale treatment system. Only a 500 mg/L dosage could perform well enough to achieve the promulgated standard of 100 ppb trihalomethane remaining in the finish water.

Francis T. Mayo, Director
Municipal Environmental Research Laboratory

ABSTRACT

This research program was initiated with the overall objective of determining the effect of powdered activated carbon on the removal of trace organics in the water treatment process at New Orleans, La.

The water treatment processes were modeled in specially designed bench scale reactors which allowed control of treatment variables. A series of experiments were conducted which incorporated the same treatment parameters as the full scale plant. Three powdered activated carbon dosages of 5, 50 and 500 mg/L were added at different locations in the bench scale treatment scheme and the analytical results were compared to a blank with no PAC.

The results of the project indicated that the 5 mg/L dosage of PAC did not improve the removal of trace organics over the normal full scale treatment system. Only the 500 mg/L dosage could perform well enough to achieve the promulgated standard of 100 ppb trihalomethane remaining in the finish water.

This report was submitted in fulfillment of Grant No. R804404 by Roy F. Weston, Inc. and University of New Orleans under subcontract to the New Orleans Sewerage and Water Board under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period June 1976 through September 1979.

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LIST OF ABBREVIATIONS

°C	Degrees Centigrade
°F	Degrees Fahrenheit
AMU	Atomic Mass Unit
BOD	Biochemical Oxygen Demand
Cl_2	Chlorine
cm	centimeters
conc	Concentrated
ev	Electron Volt
EPA	Environmental Protection Agency
FID	Flame Ionization Detection
Flur	Fluorescence
GC	Gas Chromatograph
HMW	High Molecular Weight
ITHM	Instantaneous Trihalomethane
L	Liter
lb	Pounds
m	Meters
mg	Milligrams
MG	Million Gallons
MGD	Million Gallons Per Day
mg/L	Milligrams per Liter
Min	Minutes
ml	Milliliters
mm	Millimeters
MS	Mass Spectometry
mv	Millivolt
NIH	National Institute of Health
nm	Nanometers
PAC	Powdered Activated Carbon
pH	Hydrogen Ion Concentration
ppb	Parts Per Billion
ppm	Parts Per Million
RFM	Rapid Fluorimetric Method
rpm	Revolutions Per Minute
sec	Seconds
THM	Trihalomethane
THMFP	Trihalomethane Formation Potential
TTHM	Total Trihalomethane
TOC	Total Organic Carbon
µg/L	Micrograms/Liter
µl	Microliters
UNO	University of New Orleans
UV	Ultraviolet
VOA	Volatile Organic Analysis

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The University of New Orleans Center for Bio-Organic Studies directed by Dr. John L. Laseter was responsible for the organic analyses. Dr. Edward B. Overton served as Principal Investigator for the University's work.

Roy F. Weston, Inc. was responsible for the experimentation. Mr. A. Bert Chandler conducted the experiments while Mr. Larry G. Copeland and Dr. Kelly M. Peil were Project Director and Project Manager respectively.

Mr. Jim F. Becnel, New Orleans Sewerage and Water Board Water Purification Superintendent, coordinated results.

The Environmental Protection Agency provided partial funding of the project and monitored its progress. Mr. Jack DeMarco, Chief of Field Evaluation Activities and Mr. Ben Lykins, Research Engineer were EPA's project officers.

EXECUTIVE SUMMARY

Some possibly carcinogenic compounds were identified in the New Orleans Carrollton water treatment plant's finished water during a 1975 survey. The Sewerage and Water Board which operates the treatment plant retained consultants to assist them in learning more about the compounds and their removal. The EPA funded a project to investigate the effectiveness of powdered activated carbon in removing these trace organics.

The experimental program consisted of six experiments to include two plant profiles, a carbon screening, and three studies to investigate the best location for PAC addition. The profiles identified the types of organics in the raw water and how they were modified or removed by the normal water treatment system. Carbon screening was used to select one of four carbons to use in the remainder of the project. ICI America, Inc., Hydrodarco B PAC was selected. Three experiments investigated the effectiveness of PAC dosages of 5, 50 and 500 mg/L in raw water and in coagulated and settled water with and without chlorination.

Results of this project indicated that the 5 mg/L dosage of PAC did not improve the removal of trace organics over the normal full scale treatment system. Only the 500 mg/L dosage could perform well enough to achieve the promulgated standard of 100 ppb trihalomethane remaining in the finished water. Addition of PAC to the raw water was as effective as adding it to coagulated and settled water.

A dosage of 500 mg/L PAC would create an economical and sludge handling problem for most water treatment plants. Further work needs to be done to investigate the effects of using PAC in the dosage range of 50 to 500 mg/L.

SECTION 1

INTRODUCTION

1.1 BACKGROUND

The Carrollton Purification Plant of the New Orleans Sewerage and Water Board provides potable water for approximately 550,000 residents of the East Bank portion of Orleans Parish. The nominal rate of consumption for the area served by this plant is 130 million gallons per day (MGD). Of that consumption, approximately 100 MGD is supplied by conventional coagulation-sedimentation treatment. Additionally the Dorr-Oliver Hydrotreator upflow units supply a constant 30 MGD. Normally, water from both treatments would be integrated during secondary settling but, for purposes of this study, only the conventional treatment was involved. This was accomplished by segregation of the process streams from the two types of treatment so that they did not mix until after the final treatment step, namely, filtration. However, it is very likely that any sample taken from the distribution network will contain significant portions of water from both types of treatment.

1.2 CONVENTIONAL PLANT PROCESS DESCRIPTION

The Carrollton Purification plant intakes are located at Mile 104 ahead of passes on the east bank of the Mississippi River. At the intake surface, sprays divert floating matter and four inch mesh gratings prevent uptake of large pieces of solid matter. Water is drawn through two 48 inch diameter pipelines and one 72 inch pipeline over a levee and into the low lift pumps. At the river intake potassium permanganate is added for oxidation of color, taste and odor causing compounds, fluoride is added in the form of hydrofluorosilicic acid (H_2SiF_6) for control of dental carries, and a cationic polyelectrolyte is added for flocculation of suspended matter. Mixing of these additives occurs in the low lift pumps and during flow through two 48 inch diameter and one 60 inch diameter pipelines to the plant which is located one mile from the pumps.

Upon entry into the plant, the water flows into a slow-mix basin where a solution of ferrous sulfate to aid coagulation and a lime suspension for pH adjustment and partial softening are added. The water is mixed by mechanical paddles for the approximately 30 minutes duration of its passage through this basin.

The water then flows into a sedimentation basin of approximately 10 million gallons capacity. Continuous sludge removal is accomplished by means of a mechanical rake and sludge pump intakes along the botton of the basin. The theoretical detention time in this basin is 2.4 hours for a 100 MGD rate. However, experiments using potassium permanganate as a tracer indicate that, by means of mixing and short circuiting, water begins to emerge from the basin after only 50 minutes.

The clarified water exits the sedimentation basin over a horseshoe weir. At this stage, turbidity averages 15 N.T.U.'s and pH averages 9.92. The water is immediately disinfected by addition of chlorine gas at an average dosage of 5.0 parts per million. Next it flows into a series of passages and is distributed, in parallel, into a group of eight secondary settling basins, totalling 90 million gallons of capacity. The theoretical detention time in secondary settling is 21.9 hours for a 100 MGD rate but tracing with permanganate indicates that water begins to exit after about 2.5 hours.

After secondary settlings,a solution of sodium hexometaphosphate is fed at a dosage of 0.5 ppm for stabilization of the water to inhibit excessive scale deposition. When necessary, a second dosage of chlorine fed at this point is 0.5 ppm. The necessity for secondary chlorination is determined by chlorine residual monitoring of the filter effluent.

Filtration through rapid sand filters of 30 inch sand depth is the final treatment step.

During periods of low consumption, some water is pumped into ground level storage tanks to supplement plant production during high consumption periods or for use in filter backwashing. Otherwise, the water is pumped directly into the distribution system.

1.3 HISTORICAL DEVELOPMENT OF PLANT AND TREATMENT

The Carrollton Water Plant began delivering treated water to consumers on February 9, 1909. Its nominal capacity was 40 MGD, the rating of the 10 rapid sand filters based on 2 gpm/ft.^{2}

The treatment scheme introduced raw water from the Mississippi River into the "grit" basins, round-end baffled units which removed the heavier sediment. The effluent was introduced into the "lime" basins, also round-end baffled units and into which a slaked lime solution was added.

The pH of the Mississippi is approximately 8. In order to effect coagulation, this pH would have had to be lowered for alum coagulants and then ultimately raised for protection against corrosion or the pH could be raised initially and ferrous coagulants utilized. Earlier experiments had indicated that the lime-ferrous scheme was superior and with ferrous sulfate becoming commercially available, this scheme was utilized in the plant.

The effluent of the "lime" basins which now had been partially softened and had a minimum pH of 10 was then dosed with a ferrous sulfate solution, mixed and sent to "coagulation" or settling basins. These basins had a volume of 40 million gallons and allowed approximately 24 hours of retention time before filtration with plant operations at nominal capacity. Disinfection was initiated in 1911 by the addition of chlorine in the form of Calcium Hypochlorite after filtration. The finished water was pumped directly to the consumers or put into a 15 MG clear water reservoir for use as filter back wash water and for later supply to the consumers when demand warranted.

The City grew and the Carrollton Water Plant was expanded in the early 1930's. A new chemical handling building was constructed, round-end baffle units of approximately 100 MGD were added, additional coagulation basins were built, sized in keeping with 24 hour detention time, and 18 filters totalling 72 MGD of capacity were added. The nominal rated capacity of the Carrollton Plant became 112 MGD.

Chloramines were first used in 1933, wherein ammonia in the form of ammonium sulfate was added along with chlorine prior to filtration. Quoting early records, it was "a combination which was very effective in improving the condition of the filter beds."

The use of chlorine in ton cylinders started in 1934 at an applied rate of 6 lbs./MG to the average flow rate of 55 MGD.

Water usage increased in the city. The water treated in 1952 averaged 108 MGD. Expansion and modernization was apparent in the mid 1950's.

In 1954 chlorination equipment was installed which allowed the use of single unit chlorine tank cars. With this advancement, prechlorination to the breakpoint began in the latter months of that year, to combat recurring taste and odor problems and algae growth in the settling basins.

By 1960 the following renovations had been achieved:

1. The "grit" basins in the original plant had been converted into two Dorr-Oliver Hydrotreator upflow units each rated at 50 MGD. Chlorine was added to the incoming raw water in these units.
2. The "grit" basins from the 1930 addition had been mechanized by the addition of flash mixers, slow mix paddles, and continuous sludge removal rakes into the present "conventional" basins, rated at 100 MGD each, essentially becoming "lime" basins. The effluent of these basins was chlorinated.
3. A second filter gallery with 16 filters having a total additional capacity of 120 MGD had been constructed. Provisions had been made for additional chlorination prior to filtration, when needed. The addition of this separate filter facility necessitated the abandonment of chlorination after filtration. The use of ammonia had decreased gradually and was completely discontinued in June, 1958.

4. Other minor improvements such as gravimetric feeders, lime slakers and increased clear water storage tanks had been installed.

The Carrollton Plant now has a nominal filter capacity of 232 MGD and a firm treatment capacity of 150 MGD, even considering that one "conventional" unit and one Dorr-Oliver unit can be out for servicing simultaneously. It is believed that minor upsets in the treatment process can be handled by the intermediate settling basins whose detention time approximates 24 hours.

1.4 SCOPE AND OBJECTIVES

The scope of the Sewerage and Water Board project involved the bench scale testing of Powdered Activated Carbon (PAC) to determine its efficiency for removal of trace organic contaminants. Several experiments were designed to investigate the effect of PAC addition at various locations in the existing water treatment scheme. (See Section 4)

The objectives of the project were as follows:

1. Learn more about the occurrence of trace organics in New Orleans' raw water supply, determine if additional organics are formed during treatment or if existing organics are altered and how these organics can be removed or modified during the treatment process.
2. Evaluate on bench scale the effectiveness of PAC in removing these trace organics (both their original and modified forms) and the effect of PAC addition location (at which point in the treatment process) with respect to the chlorination location upon removal efficiency or reduction of formation of chlorinated organics.
3. Evaluate four general analytical techniques insofar as their applicability as control parameters for use by treatment plant operators as indicators of trace organics. Techniques evaluated were: ultraviolet (UV) absorbance at a fixed wavelength, UV absorbance over a range of wavelength (UVscan), fluorescence at a fixed wavelength and fluorescence over a range of wavelength (fluorescence scan).

1.5 OVERVIEW OF EXPERIMENTAL DESIGN AND PROCEDURES

In order to accomplish the objectives of the study the following were performed:

1. Bench scale experiments were designed to simulate possible PAC addition points within the Carrollton water treatment plant.
2. Bench scale apparatus and specific project laboratory facilities were located in an on-site trailer.
3. Two plant water quality profiles were conducted to establish background data for comparison with bench scale studies. These plant profiles involved sampling the water at several points in the full scale treatment process and then analyzing the samples.
4. Several representative brands of PAC (Appendix F) were evaluated to determine that best suited for use in the remainder of the experimental work. Varying dosages of the selected PAC were utilized to treat on a bench scale water samples which were representative of water as it occurs at various points in the treatment process. The treated samples were analyzed for parameters indicative of trace organics, namely: total organic carbon, specific organic compounds, and trihalomethanes.

SECTION 2

CONCLUSIONS

The conclusions from this experimental study are reported below with respect to the three objectives of the project which were presented in Section 1.

The first objective was briefly to determine the occurrence of trace organics and how these compounds are removed in the normal water treatment process. The conclusions were as follows:

1. Fifteen of the 37 trace organic compounds of interest were identified. Eight of these 15 were volatile and 7 were HMW compounds.
2. The raw water has a significant quantity of THM precursor (500-700 ppb). Approximately 50% of the precursor is removed by normal treatment.
3. Chloroform is the predominant THM form.
4. The normal treatment process removes a portion of influent HMW compounds. For those HMW compounds which were most prevalent removals in the range of less than 20% to greater than 60% were observed. Raw water values for these compounds were generally in the range of 0.4 to 1.4 μg/L.

The second objective was to evaluate the effectiveness of PAC addition to the treatment plant for the removal of trace organics. The conclusions were as follows:

1. PAC dosage in the 50-500 mg/L range will be required to achieve significant reduction of THM potential.
2. The location at which the PAC is added does not appear to effect THM removal efficiency, for the locations tested.

The third and final objective was to evaluate four general analytical techniques as control parameters for trace organics. The only conclusion which could be drawn was as follows:

1. The four tests do exhibit some potential as substitute indicators for THM. However, significant work will be required to determine if the approach is valid.

SECTION 3

RECOMMENDATIONS

3.1 GENERAL

The major objective of this study was to provide data as to the feasibility of economically controlling suspected carcinogens in drinking water supplies by PAC. This study focused on a specific group of hydrocarbons, the THMs. While these compounds do not constitute all the suspected carcinogens of interest, they and other chlorinated hydrocarbons are of significant concern. Chloroform was a predominate form in the treated water addressed in this project.

3.2 METHODS TO CONTROL THM

A standard of 100 ppb has been promulgated for trihalomethanes (major one being chloroform) in finished drinking water. Three ways to control this parameter (and thereby the total concentration of chlorinated hydrocarbons) are:

1. Remove the precursors
2. Control the conversion of precursors to the THM form
3. Remove the THMs after formation

This study examined PAC as a means for removing THM precursors. The data has shown that a dosage greater than 50mg/L will be required if control of precursor alone is to be utilized for THM control. A dosage of 500mg/L PAC produced water with less than 100µg/L THM. It is very questionable whether this is economically viable or feasible from the standpoint of PAC addition and sludge removal.

The second method involved utilizing normal treatment techniques, such as coagulation sedimentation, but utilizing alternative disinfection techniques such as substituting ancillary method for initial disinfectant and providing low chlorine dosages for protection against contamination in the distribution system. The lower chlorine concentration would result in a slower reaction rate of conversion of precursor to THM. This, in turn would reduce the THM formed during the detention times in the system.

The third method to control THMs was not addressed in the study. Possibly a PAC could be produced which is selective for the removal of chloroform (not the precursors).

3.3 ADDITIONAL STUDY REQUIRED

It would be beneficial to execute additional investigative approaches to pursue the viability of areas of investigation listed below:

1. The use of PAC as a method to remove precursors was evaluated. The data demonstrated that only the 500mg/L dosage was acceptable; however, the 50mg/L was marginal. Further studies are required to see if a dosage closer to 100mg/L would be as effective as the 500mg/L dosage. This data would allow an economic evaluation to be made as to PAC's suitability for use in removing precursors either above or in combination with other techniques.
2. The study indicates that PAC removed higher percentages of chloroform than other identified percursors. It is possible that PAC formulations have been developed which selectively remove specific THM precursors. A study should be implemented to evaluate the effectiveness of specific PAC formulations on removal of priority precursors from water.

3. An overall economic and performance evaluation of approaches suggested previously should be implemented. Several schemes could be evaluated:
    - PAC addition to raw water before chlorine disinfection
    - PAC addition to raw water after chlorine disinfection
    - PAC addition to coagulated/settled water with chlorine present
    - PAC addition to coagulated/settled water without chlorine present
    - Alternate pre-disinfectants plus PAC and post chlorination
    - PAC addition at the end of the conventional treatment scheme

SECTION 4

MATERIAL AND METHODS

4.1 ON-SITE LABORATORY

A separate experimental facility was necessary because of space limitations in the water treatment plant buildings and the desirability of decreasing the potential for experiment contamination from the surroundings. For this reason, a 3.7 by 18.3 meter mobile trailer was positioned at the plant. This trailer was divided into two rooms. One room was equipped as an office. The second was equipped as a laboratory in which water treatment processes were simulated.

The laboratory was provided with climate control (air conditioning and heating) and potable water. Major items of equipment included: furniture (desks and benches), a sink, distillation equipment, Mille-Q filtration equipment, a vacuum pump, refrigerator, incubator, analytical equipment to measure ultraviolet (UV) absorbance and fluorescence and apparatus to simulate the water treatment process. The latter item is described below.

4.2 WATER TREATMENT PROCESS SIMULATION APPARATUS

Either raw water or coagulated water could be pumped into either or both of two 2,350 liter (620 gallon) stainless steel feed tanks. The tanks were located on a dike structure above the trailer to permit gravity flow into the trailer. Both tanks were equipped with 1/3 horsepower mixers while one of the tanks had exit ports at various levels for decanting or sampling liquid. Chemical treatment of the raw water could be effected in the feed tanks.

Effluent from the feed tanks entered a manifold pipe to permit the filling of any of nine reactors in which water treatment was simulated (see figure 4.1). Each reactor consisted of a 22 liter Pyrex glass container equipped with a glass stop cock and Teflon plug. The top of the reactor was a separate piece of Pyrex secured by a clamp. This top had three ports. Two of the ports were ground glass and were utilized for adding chemicals to and removing samples from the reactor. The third port contained a permanent glass stirring rod and was water sealed. The stirring rod was connected to a Cole Parmer variable speed stirrer.

The reactors were used to model coagulation, settling and carbon contact processes. The partially treated water was then drained from the reactor directly into a porcelain Buchner funnel for filtration. A Reave-Angel AH934 fiber-glass filter was used to simulate a sand bed. The filtered water flowed through a Teflon hose directly into a 20 liter carboy. A slight negative pressure was maintained on the carboy to speed filtration. A vacuum pump was used intermittently to create the vacuum. Sample bottles for analytical determinations were filled from the carboy.

4.3 EXPERIMENTAL PROTOCOLS

A detailed experimental protocol was prepared and approved prior to initiation of the program. The various experiments were conducted by procedures detailed in the protocol. All samples from one experiment were analyzed before a second experiment was conducted. This served to minimize storage time and to allow subsequent experiments to be modified, if necessary, by results of previous experiments. The single departure from this procedure was necessary because the experimental protocol required that the same water supply be used for two experiments.

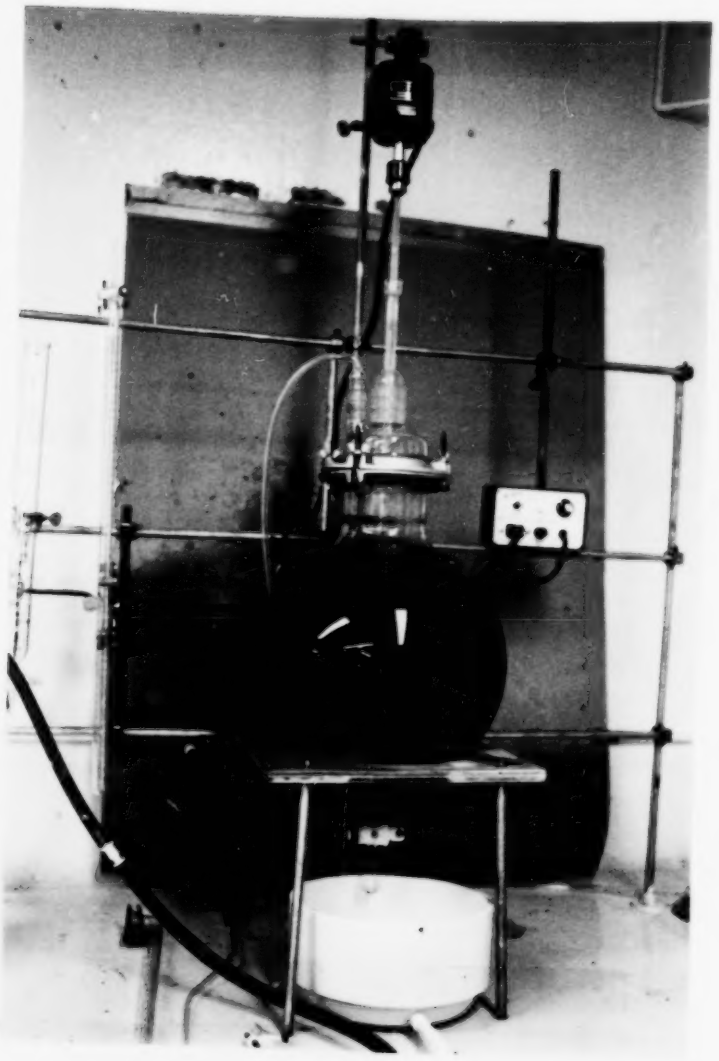

FIGURE 4.1

General View of Contact Apparatus and Carbon Removal Filter
– Illustrating Carbon Suspension/Contact Mode of Operation

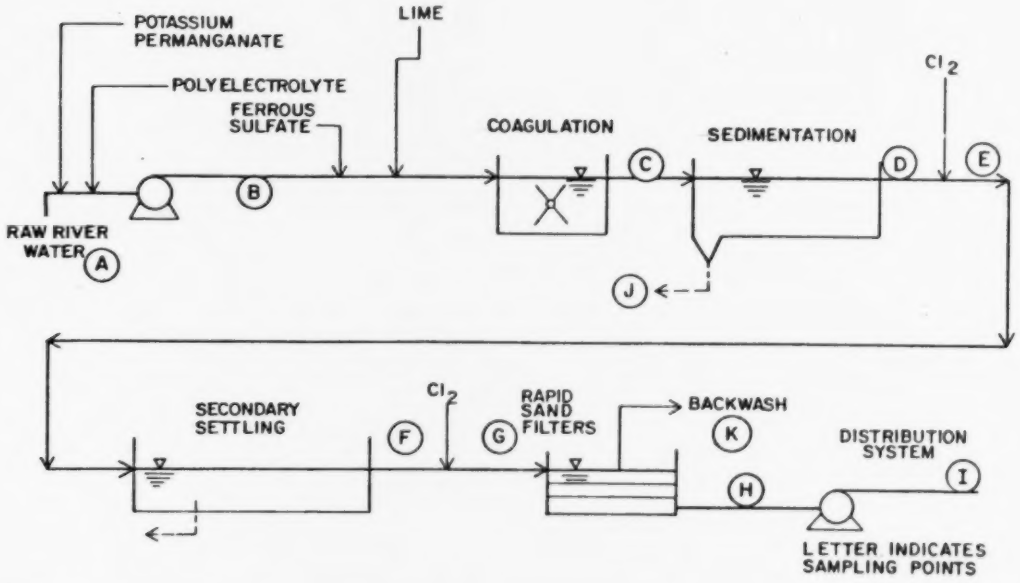

FIGURE 4.2 Schematic Flow Diagram of Carrollton Water Treatment Plant

4.4 EXPERIMENTAL DESIGN

The following is a list of the major experiments conducted:

1. Plant Profiles – These experiments served to determine the level of trace organics at various locations in the full scale water treatment process. They involved sampling at eleven points at the Carrollton facility and analyzing these samples for various parameters which are discussed in Section 6 and presented in the Appendix. (See Fig. 4.2). Two plant profiles were conducted.
2. Chlorination Studies – These experiments served to determine the effect of chlorination at various points in the water treatment process on the formation of trihalomethanes. They involved simulating the treatment process at the Carrollton plant with either single stage or two stage chlorination. Samples were taken and analyzed for the various trace organics. Since the two chlorination studies were performed in conjunction with the profiles, these data also allowed plant scale and bench scale experiments to be compared.
3. Carbon Screening Study – This experiment served to determine which of several brands of PAC was best suited for use in subsequent investigative studies in this project. It involved dosing coagulated/settled water from the plant with varying dosages of various brands of PAC and analyzing the resultant water for specific organics and other parameters.
4. Investigative Studies – These experiments served to determine the effectiveness of the selected PAC in removing trace organics and the relationship of PAC addition location on this effectiveness. They involved dosing water taken at different points in the water treatment process (treatment simulated in reactors) with varying concentrations of PAC. Three investigative studies were conducted.

Each experiment is described in the following sections:

4.5 PLANT PROFILES

The two profiles were selected to be indicative of two separate river conditions. The profiles were intended to describe the pattern of occurrence of trace organics in the river water and how these compounds are removed or modified as the water goes through the treatment process. The two plant profiles are described below:

The first profile was performed in September, 1978, during low river flow conditions. Figure 4.2 is a representation of the eleven sampling sites utilized for the profile. Sample Point I was a tap at the University of New Orleans (UNO). This location provided nearly five days travel time from the head end of the plant. This was selected because it represents the furthest point in the distribution system. The samples were gathered in a time sequence which resulted in each sample being taken from the same slug of water as it passed through the plant.

4.5.2 Second Plant Profile

The second plant profile was conducted in April 1979, during peak river flow conditions. Procedures were identical to those described in 4.5.1.

4.6 CHLORINATION STUDIES

On the same day that the plant profiles were taken, bench scale experiments were performed to compare the effects of the following possible treatment schemes on the formation of trihalomethanes: 1) two stage chlorination of water before and after secondary settling and, 2) single stage chlorination after secondary settling. Plant coagulated and settled water was used. In the first reactor the water was chlorinated and allowed to settle, chlorinated a second time and filtered. These steps simulate the full scale treatment process and the results of this bench scale test were compared to full and bench scale operations. The second reactor was treated in the same manner as the first reactor with the elimination of first stage chlorination.

4.6.1 First Chlorination Study

The first chlorination study was conducted in conjunction with the first plant profile. The plant coagulated and settled water was pumped into the head feed tanks. Lines to two of the reactors were flushed with the clarified water and then those two reactors were filled with the clarified water. The third reactor was filled with Mille-Q filtered water thus serving as a control.

One reactor and the control were chlorinated to 8mg/L chlorine while the other reactor was not chlorinated. A 10 minute contact time (with mixing) was used and all three reactors were allowed to settle for three hours. The coagulated/settled water was then decanted into clean reactors. The previously chlorinated plant water and the control received an additional 1mg/L dose of chlorine while the unchlorinated plant water received its first dose of chlorine at 3mg/L. The 3mg/L value was selected because it was believed typical of chlorine dosages which would be required at the plant if it were in a single chlorination mode. A 10 minute contact time (with mixing) followed before the contents of all three reactors were filtered into carboys for sampling.

Table A.13 shows the free chlorine residual in the reactors before the sample bottles were dosed with chlorine for the terminal THM determination. The 2-stage chlorination had a residual of 8.90 mg/L and was not dosed with additional chlorine. The 1-stage chlorination was 1.8 mg/L and was dosed to produce 8.0mg/L for the terminal THM determination.

4.6.2 Second Chlorination Study

The second chlorination study was conducted in conjunction with the second plant profile. The procedure described in 4.6.1 was utilized with the exception that a 5 mg/L chlorine dosage was substituted for the 8mg/L dosage. This was a typical dosage for the time of year.

4.7 CARBON SCREENING

The various powdered activated carbons (PAC) available exhibit different absorptive characteristics. Therefore, it was necessary to perform preliminary screening studies to select a carbon applicable for removal of contaminants of interest. Four different manufacturers were contacted to supply a PAC which they felt was best suited for this application. The four carbons received were Amoco PX-25, Westvaco Aqua Nuchar, Husky Industries Water Carb Plus, and ICI America, Inc. Hydrodarco B. Additional data on the carbons may be found in Appendix F. The three doses of PAC selected to determine removal efficiency of trace organics were 5, 50 and 500 mg/L. Coagulated and settled water from the full-scale treatment plant was used in the screening test. Two consecutive days were required to accomplish the screening study because only nine reactors were available. The test procedure is described in the following paragraphs.

The head feed tanks and all lines were flushed with the plant's coagulated and settled water. The tanks were filled and drained twice before the final filling for testing. Eight reactors and all ancillary equipment were cleaned (see Sec. 5) and assembled for the test. All eight reactors were filled with 20 liters of the feed tank water. Two reactors were randomly selected to be a stirred and unstirred control with no PAC utilized. The other six reactors were dosed with the PAC; i.e., three reactors with 5, 50 and 500 mg/L of Westvaco and three reactors with the same dosages of ICI PAC. The reactors were stirred at 40 rpm for 30 minutes. Reactor contents were then filtered through Reave Angel AH934 fiberglass paper into a carboy. Sample bottles were filled from the carboy for later analyses.

All the equipment was cleaned and re-assembled for the second day experiment. Six reactors were used for the 5, 50 and 500 mg/L dosages of Husky and Amoco PAC. The same procedure was followed for these two carbons as for the first two carbons.

4.8 INVESTIGATIVE STUDIES

After all data from the carbon screening were evaluated, ICI PAC carbon was selected for use in investigative studies.

Three investigative studies were conducted:

- Investigative Study No. 1 was intended to simulate the addition of PAC to raw water prior to coagulation, sedimentation and filtration.
- Investigative Study No. 2 was intended to simulate the same conditions as Study No. 1 plus the addition of chlorine prior to filtration to a portion of the reactors.
- Investigative Study No. 3 was intended to simulate PAC addition after coagulation/sedimentation with and without a final chlorination step.

All of the above studies evaluated PAC addition before any disinfection.

4.8.1 Investigative Study No. 1

The first experiment was designed to simulate the addition of PAC to raw water prior to coagulation, sedimentation and filtration. The plant water treatment process was simulated in the reactors with the exception that chlorination was eliminated. The test procedure is described below.

All chemical additions to the full-scale plant raw water were shut off and this water was pumped to the head feed tanks. The tanks and lines were flushed before filling the reactors. Nine reactors were used as follows:

1. Raw water and 5 mg/L PAC.
2. Raw water and 50 mg/L PAC.
3. Raw water and 500 mg/L PAC.

4. Raw water stirred control with no PAC.
5. Raw water unstirred control with no PAC.
6. Mille-Q water control with no PAC.
7. Mille-Q water control with 5 mg/L PAC.
8. Raw water and 5 mg/L PAC with water washed filter paper.
9. Raw water and 5 mg/L PAC with acid and water washed filter paper.

The two Mille-Q water reactors were used to determine if any contaminants were being added by the PAC. The final two reactors were used to evaluate the possibility of filter paper contamination. Throughout the remainder of the study it was not standard procedure to wash the filter paper with acid.

PAC was contacted for 30 minutes at 40 rpm and all reactors except the unstirred control were stirred at the same time. Plant chemicals were added after the 30 minute contact time at the normal full scale concentration to all reactors except the unstirred control and the two Mille-Q controls. The chemicals and resulting concentrations were: polyelectrolyte (cationic) at 1.5 mg/L, potassium permanganate at 0.65 mg/L, hydrofluorosilicic acid (H_2SiF_6) at 2.9 mg/L, ferrous sulfate at 3.5 mg/L, and lime (CaO) at 54 mg/L. These chemicals were added to model the normal full scale plant operating procedures. Contents of the reactors were mixed for 30 minutes at 60 rpm and allowed to settle for 3 hours. A three liter volume was removed from each reactor. The remaining reactor contents were filtered into carboys for subsequent analysis.

4.8.2 Investigative Study No. 2

Again using untreated raw river water, the second experiment was conducted a month later than Test No. 1. This test included: 1) a duplication of Test No. 1 and, 2) a duplication of Test No. 1 with chlorination prior to filtration. The same PAC dosages were used. The procedure is described in the following paragraphs.

As done previously in Study No. 1, chemical additions to the plant raw water were shut off and this water was flushed through the head feed tanks and lines before filling both tanks for the experiment. Nine reactors were used with varying dosages of PAC and chlorine as listed below:

1. Raw water and 5 mg/L PAC.
2. Raw water and 50 mg/L PAC.
3. Raw water and 500 mg/L PAC.
4. Raw water stirred control with no PAC or chlorine.
5. Raw water stirred control chlorinated with no PAC.
6. Raw water unstirred control with no PAC or chlorine.
7. Raw water and 5 mg/L PAC and 3 mg/L Cl_2.
8. Raw water and 50 mg/L PAC and 3 mg/L Cl_2.
9. Raw water and 500 mg/L PAC and 3 mg/L Cl_2.

All nine reactors were filled with 20 liters of raw water from the head feed tanks and PAC was added at the pre-selected dosages and contacted for 30 minutes at 40 rpms. The five chemicals described in Test No. 1 were added to all the reactors except the unstirred control. The chemicals were contacted for 30 minutes at 60 rpm and then allowed to settle for 3 hours. Settled solids were removed. A 3 mg/L dosage of chlorine was added to one stirred control and three of the reactors with PAC. This value was selected as a typical value for single step chlorination. After a 30 minute contact time (with mixing) the water was filtered. The reactors not receiving chlorine were filtered after the 3 hour settling period.

4.8.3 Investigative Study No. 3

The third experiment was conducted the day after Test No. 2 using raw water obtained the day of Test No. 2. This experiment compared carbon treatment after coagulation/sedimentation with and without a final chlorination step. The procedure is detailed below.

The five chemicals described above for coagulation/settling and raw water treatment were added to the head feed tank, mixed and allowed to settle for 30 minutes. Water was taken from near the top of the tank to fill the nine reactors. All lines were flushed and a 20 liter volume was used in each reactor. Nine reactors were used with varying PAC and dosages of chlorine listed below:

1. Coagulated/Settled water and 5 mg/L PAC and no Cl_2.
2. Coagulated/Settled water and 50 mg/L PAC and no Cl_2.
3. Coagulated/Settled water and 500 mg/L PAC and no Cl_2.
4. Coagulated/Settled water stirred control with no PAC and no Cl_2.
5. Coagulated/Settled water stirred control with no PAC and 3mg/L Cl_2.
6. Coagulated/Settled water unstirred control with no PAC or Cl_2.
7. Coagulated/Settled water and 5 mg/L PAC and 3 mg/L Cl_2.
8. Coagulated/Settled water and 50 mg/L PAC and 3 mg/L Cl_2.
9. Coagulated/Settled water and 500 mg/L PAC and 3 mg/L Cl_2.

The PAC was contacted for 30 minutes and allowed to settle for 2.5 hours. Settled solids were removed. A 3 mg/L dose of chlorine was added to one stirred control and three of the reactors with PAC. After a 30 minute contact time, the contents of each reactor were filtered through Reave Angel AH934 paper into their corresponding carboys. Sample bottles were filled from the carboys and prepared for analysis or shipment to the Unversity of New Orleans (UNO).

SECTION 5

EXPERIMENTAL PROCEDURES

5.1 GENERAL PARAMETERS

This section of the report will describe the procedures used to gather samples, store samples and analyze samples. Subsection 5.1 contains a discussion of the general parameters and the trihalomethane analyses, while subsection 5.2 contains a discussion of the organic analyses.

5.1.1 Cleaning Procedure

A specific cleaning procedure was established for all reactor and sample contacted equipment in the field laboratory. All equipment was cleaned before initial use and after each successive use as detailed below:

1. Prepare chromic acid cleaning solution by adding chromerge reagent one (1) bottle to a 4.1 kilogram (9lb) bottle of reagent grade sulfuric acid (conc.).
2. Heat the chromerge-sulfuric acid to just below the point where the acid begins to fume.
3. Treat all equipment with enough hot chromerge to completely coat the inside (contact surface) of the glassware, etc. Rotate the equipment to assure surface is completely coated. Allow to stand 5-10 minutes.
4. Rinse with copious quantities of tapwater to remove all traces of chromerge.
5. Rinse several times with Mille-Q treated water.
6. Invert on clean dry absorbent material and allow to drain.
7. Cover with protective material to exclude dust and other contaminants.

5.1.2 Preservation/Distribution of Samples

All organic samples were collected in amber, one liter bottles that had been washed and supplied by the University of New Orleans. Samples from each carboy were place in five of these bottles; three for High Molecular Weight (HMW) analysis; one for volatile analysis and one for Total Organic Carbon (TOC) analysis. Three 25ml vials and one 25ml vial were filled from the amber bottles for the volatile and TOC analyses, respectively. This permitted easier transfer of the treated water from a carboy to a vial. Before collecting the samples, one half milliliter of a 10% sodium thiosulfate solution was added to each bottle, except for the TOC bottle. This was required to stop any chlorine reaction. Blanks were treated the same as the samples. All samples were stored in the refrigerator until analyses. The HMW, volatile and TOC samples were analyzed by the University of New Orleans. The remainder of the samples were analyzed as discussed below.

The remaining samples were used to perform pH, turbidity, color, ultraviolet, fluorescence and terminal THM analyses. The THM incubation was performed in the on-site laboratory. The samples for color, ultraviolet and fluorescence measurements were filtered through a 0.45mm filter in order to eliminate any possible interferences from turbidity.

5.1.3 Temperature, Turbidity, Color

The tests were not performed in any formalized order, except for temperature and turbidity. Temperature was measured at the site where the sample was collected. Turbidity was measured using a Hach 2100A Turbidimeter with Hach calibrating standards. Color determination was carried out according to the "visual comparison method" from the 14th edition of *Standard Methods for the Examination for Water and Wastewater;* however, the water was not pH adjusted. The same laboratory technician performed all color tests throughout the study.

5.1.4 Ultraviolet and Fluorescence Analyses

The ultraviolet (UV) measurements were conducted according to Brodtman (1) and Dobbs, et al (2). The Brodtman Method utilized wavelengths from 270 to 190 nm, while the Dobbs Method used wavelengths from 400 to 230nm. In order to cover both methods, samples were scanned from 400 to 195 nm. The instrument, a Beckman Acta MIV, was zeroed with sodium thiosulfate spiked Mille-Q water at 400 nm. The servo mechanism was on and the bandwidth was set to 1 nm. Samples were then placed into the instrument and the wavelength scanned from 400 to 195 nm at 1 nm/sec. Immediately following the scan, the wavelength was placed on 254 nm and the absorbance of the sample was recorded.

The Rapid Fluorimetric Method (RFM), Sylvia (3), was employed to measure the fluorescence. An ovaline standard (permanent polymer standard, Perkin-Elmer #520-7440) was placed into a Perkin-Elmer 204A Fluorescence Spectrophotometer and calibrated at an excitation wavelength of 340 nm and an emission wavelength of 390 nm.

The Total Emission Fluorescence was performed on all the samples. This method involved setting the 104A at an excitation wavelength of 310 nm and scanning the emission wavelength from 370 nm to 580 nm.

Areas for the scans were computed by the cut-and-weigh method for the first profile and carbon screening because there was no other method available. After obtaining a planimeter the remaining areas were measured by this method. All final values were derived by subtracting blank readings from sample readings.

1. Brodtman, N. "Granular Activated Carbon Studies" 1978, pp. 22, EPA Interim Report No. R-80457101.
2. Dobbs, R., Wise, R. and Dean, R. "The Use of Ultraviolet absorbance for Monitoring the Total Organic Carbon Content of Water and Wastewater". Wtr. Res. C (1972).
3. Sylvia, A.E. "Detection and Measurement of Microorganics in Drinking Water". J.NE. W.W.A. 87:2 (1973).

5.1.5 Chlorine Residual Determination

Free chlorine residual and total residual chlorine (free and combined) were measured by means of titration with phenylarsine oxide employing a Fisher Porter amperometric titrator.

A 200 ml aliquot of each sample was taken immediately upon filtration or aspiration from the reactor, depending upon which portion of the investigation was involved. The sample was buffered to pH 7.0 and titrated for free chlorine to an accuracy of $\pm$ .03 parts per million.This sample was then adjusted to pH 10.0. Iodide ion was added in the form of potassium iodide and the sample was again titrated with phenylarsine oxide to determine total residual chlorine.

5.1.6 pH Determination

The pH was measured during preparation of the terminal trihalomethane samples.

Approximately 400 mls of each sample was poured into an acid washed 600 ml beaker containing an acid washed Teflon stirring bar. The magnetic stirrer was kept at its lowest speed. The pH measurement was then made using a Corning combination electrode with a Leeds & Northrup Model 7413 pH/specific ion/mv meter. The meter had previously been calibrated employing a two point calibration at pH 6.97 and pH 10.0.

5.1.7 Preparation and Incubation of Samples for Terminal Trihalomethane Determination

Immediately after recording pH, the samples were adjusted to pH 10.0 $\pm$ 0.2 using a suspension of lime from the plant lime slakers. This pH range was used to approximate the pH of water during secondary treatment and in the distribution network. If the pH of the sample was already within the above range, no lime was added. In no case was the pH above 10.2 and, therefore, no sample required acidification.

The samples were incubated in acid washed 300 ml BOD bottles. The concentrations of free chlorine already in the samples, instantaneous free residuals, were known from the amperometric titrations of the separate 200 ml aliquots. A chlorine solution from the plant chlorinator was diluted 5 mls to 1000 mls and titrated to determine its free Cl_2 concentration. This titration was performed no more than 30 minutes prior to each use of the solution. (The Cl_2 concentrations ranged from 1800 mg/L to 2300 mg/L.)

A calculation was performed to determine the correct amount of plant chlorine solution for the dosing of the terminal THM samples.

The formula used was: $A = B \times (C-D)/E$

Where:

A = mls plant chlorine solution required
B = mls sample to be dosed (310 mls)
C = parts per million free Cl_2 residual to be achieved by dosing
D = parts per million free Cl_2 residual prior to dosing
E = parts per million free Cl_2 in plant chlorine solution used for dosing

A sample volume of 310 mls was used, that amount fills a 300 ml BOD bottle to convex miniscus before insertion of the stopper, thus assuring expulsion of all air.

The necessary amount of the chlorine solution was pipetted into each bottle. Immediately, the sample, which had been pH adjusted, was poured into the BOD bottle while gently swirling to mix. These were stoppered and placed in the incubator. Five days duration and 85° F (29.4° C) were the conditions used to approximate the environment of water going to the most distant points in the distribution network during the warmest period of the year in New Orleans.

Upon retrieval at the end of the incubation period, 200 mls of each sample were again amperometricly titrated for calculation of the five day chlorine demand and to assure that a sufficient free Cl_2 residual had been maintained throughout incubation. Chlorine demand tables may be found in Appendices A-E.

Ten drops of 10% sodium thiosulfate (by weight) were then added to the remaining 100 mls of sample in the BOD bottle and mixed by gently swirling. Five mls of the sample were then tested for free chlorine residual by the DPD colorimetric method (Hach Chemical Co.) to assure complete quenching of the chlorine. Duplicate 25 ml teflon stoppered sample vials were filled and sealed with zero headspace. They were immediately refrigerated to await analysis.

Before the first plant profile, a study was conducted to determine the five day chlorine demands of raw river and coagulated-settled water. Several samples of each water were pH adjusted to 10.0 ± 0.2 and then dosed with chlorine in concentration increments of one part per million. The range of dosages was 10 mg/L – 20 mg/L for raw river and 5 mg/L – 10 mg/L for coagulated-settled water. The samples were incubated for five days at 85° F. They were then opened and titrated for free Cl_2 residual. The raw river samples were found to have decreased by approximately 17 mg/L in free Cl_2 residual during the five day period. The coagulated-settled samples had decreased by approximately 6 mg/L during that period. In order to assure a margin of safety, concentrations of 19 mg/L free Cl_2 were used to dose samples from locations (1) raw river; (2) raw river with permanganate, fluoride and polyelectrolyte and (3) coagulated water, for terminal THM analysis in the first plant profile. Similarly, a total dosage of 8.0 mg/L of free chlorine was selected for addition to each of the remaining samples (coagulated-settled through distribution) from the first plant profile.

During the course of the study chlorine demands were extremely variable. This fact is exemplified by the increased Cl_2 demand (relative to the demand study discussed above) of the coagulated-settled sample in the first plant profile, which rendered an insufficient free residual (less than 0.5 mg/L) at the end of five days of incubation. Variability in five day Cl_2 demand was highest on raw river samples. The five day Cl_2 demand of the raw river samples examined during the study ranged from 11.2 mg/L to 21.7 mg/L. This unpredictable nature of the Cl_2 demand during cold

weather, high turbidity months resulted in an inadequate free Cl_2 residual at the end of five days on the raw river sample (#034) collected during Carbon Investigation I. Henceforth, for every raw river sample, three aliquots were dosed at 20 mg/L, 25 mg/L and 30 mg/L and incubated for terminal THM analysis. At the end of the incubation period, the lowest dosed aliquot that had sustained a 0.5 mg/L free Cl_2 residual was quenched and analyzed for terminal THM.

5.2 ORGANIC ANALYSIS PROCEDURE

Organic constituents were determined as follows: Total Organic Carbon, Volatile Organic Compound Analysis by Flame Ionization Detection, Volatile Organic Compound Analysis by Mass Spectrometry, High Molecular Weight Compound Analysis by Flame Ionization Detection, High Molecular Weight Compound Analysis by Mass Spectrometry. These are discussed below.

5.2.1 Total Organic Carbon Analysis Methodology

Total organic carbon (TOC) analysis was performed on a Beckman model 915A TOC Analyzer coupled to a Beckman model 865 Infrared Analyzer.

Standard Preparation

Deionized water was acidified to pH 2.0 with concentrated hydrochloric acid (HCl) and then sparged for 10 minutes with nitrogen gas just prior to actual standard preparation. A stock solution of 1000 mg/L organic carbon was obtained by dissolving 0.2125 gm of reagent grade anhydrous potassium biphthalate ($KHC_8H_4O_4$) in a 100 ml volumetric flask. Working standard solutions were then prepared by dilution. Standard concentrations were 2, 4, 6, 8, 10, 15 and 20 mg/L. A 0 mg/L control standard was retained from the acidified deionized water used in preparing stock and working solutions. All standards were sparged with nitrogen gas for 5 minutes immediately prior to analysis.

Sample Preparation: Samples were acidified to pH 2.0 with concentrated HCl to eliminate inorganic carbon. Samples were sparged with N_2 for 5 minutes immediately prior to analysis.

Analysis

The TOC furnace was maintained at 950° C with oxygen carrier flow of 150ml/min. Injections were made with a Hamilton CR700 constant rate syringe adjusted to deliver 20 ul. Calibration and sample analysis were conducted the same day to ensure proper calibration. Calibration was initiated by first injecting the 20 mg/L solution and adjusting the gain control to obtain 100% response for this concentration. Next the standard series was analyzed from 0 mg/L – 20 mg/L by repetitive injections. Injection of a given solution was repeated at least three (3) times to ensure reproducibility of peak heights. Sample analysis immediately followed standardization. Again reproducibility of a minimum of three (3) injections was obtained before proceeding to the next sample. Injection of the 6 mg/L standard solution was repeated intermittently every fourth sample to ensure that calibration remained constant.

Data Treatment

Height of peaks was measured to the nearest 0.1 millimeter manually. An average was derived for each standard and sample. The calibration graph was generated for standard response and checked for linearity. Sample concentrations were then interpolated using this graph.

5.2.2 Volatile Organic Compound Analysis (VOA) – Flame Ionization Detection (FID)

VOA-FID were performed using the purge and trap procedure. This analysis involved purging volatile organics from a 5 ml water sample and trapping these coumpounds on a Tenax GC trap. The organic compounds are then thermally desorbed from the Tenax trap and trapped on the head of SF96 glass capillary gas chromatograph column. They are subsequently separated by temperature programmed gas chromatography and detected by flame ionization detection (FID). The purge and trap device consisted of a Tekmar LSC-1 interfaced to a Hewlett-Packard 5711A gas

chromatograph. Chromatographic data was acquired, stored and treated on a HP 3354 laboratory data system.

The following conditions were used for VOA analysis:

1. Tekmar sample purge flow rates were 14 ml/min for 30 minutes with the Tenax trap at ambient temperature.
2. The desorb flow rate was 7 ml/min at 200° C for 5 minutes.
3. Tenax trap was baked out at 14 ml/min and 275° for 1 hour between sample runs.
4. Chromatographic conditions were as follows:
   a. SF96 glass capillary column 0.4 mm x 50 m
   b. carrier gas was helium flowing at 7 ml/min
   c. detection was by FID
   d. column temperature during desorb was -20° C for 5 minutes
   e. temperature program was 20° C to 130° C at 4°/min with a 4 minute hold at 20° C
   f. integration rates (area slice width) were 0.5 seconds

Standards of all VOA compounds were made up in acetone and spiked directly into 5 ml water blanks. Blanks and standards were run each day to insure that response factors remained constant during the time of analysis.

5.2.3 Volatile Organic Compound Analysis (VOA) – Mass Spectrometry (MS)

The same purge and trap procedure used for the VOA-FID was used for VOA-MS with the following exceptions. First, a 15 ml sample purge vessel was used instead of the 5 ml vessel used for VOA-FID. Second, 15 ml of sample were used for VOA-MS. Third, the effluent from the purged sample was passed through a concentrated sulfuric acid (H_2SO_4) trap before it passed through the Tenax trap. This step removed water from the effluent and improved the quality of mass spectral data.

Sample components eluting from the SF96 glass capillary GC column were passed through a jet type separator into the ion source of the Dupont 21-491 mass spectrometer. A helium make-up gas was added between the glass capillary column and the jet separator. Eluting components were detected as peaks on the total ion monitor and their mass spectra were manually scanned. Data was recorded by an oscillographic recorder and manually interpreted by comparison of spectra with those of authentic standards. Ionization was by electron impact at 70 ev and spectra were scanned at a rate of 4 sec. per decade from 300 to 20 Atomic Mass Unit (AMU).

5.2.4 High Molecular Weight Compound Analysis (HMW) – Flame Ionization Detection (FID)

Three liters of each sample were extracted with 15% methylene chloride in laboratory distilled hexane (Burdick and Jackson). Each liter was extracted three times with 60 ml solvent. A two liter separatory funnel was shaken by hand 80 times for each extraction. All solvent layers were combined and run through a 10 x 1.0 cm sodium sulfate column. The sodium sulfate was activated in a 220° C muffler furnace approximately one hour before use. The sample was then reduced in volume by evaporation to about 2 ml and stored at 4° C until analyzed by gas chromatography.

An initial recovery standard, hexamethylbenzene, was spiked into each sample before extraction. Hexamethylbenzene was used for the quantitation of all sample compounds reported from the GC trace. All samples were also spiked before extraction with 3-methyltricosan, which was used as a marker compound to aid in alignment between GC runs.

A Hewlett-Packard 5711A gas chromatograph equipped with a glass capillary inlet system was used for sample quantitation. Samples were run in the splitless mode with a carrier (helium) flow of 2.5 ml/min. The glass capillary column was approximately 0.33 mm x 30 m, silylated, and coated with SE52.

Oven programming was set at 50° C to 240° with a variance of 4°/min. Sample extracts were reduced in volume under nitrogen to about 50 ul before injection into the GC. All samples were rediluted and returned to a freezer for storage. This sample preparation was repeated for any further analytical runs of GC-MS analysis.

5.2.5 High Molecular Weight Compound Analysis (HMW) – Mass Spectrometry (MS)

Chromatographic conditions were the same as those used for HMW-FID analyses. Eluting components were introduced directly into the ion source of a Varian MAT 311A mass spectrometer without passing through an enrichment device. Mass spectral data was acquired and treated on a Varian Spectra 100 data system. The instrument was operated in the continuous scan mode with a cycle time of 3.8 seconds. Mass spectra were scanned from 35 to 600 AMU and ionization was by electron impact at 70 ev. Two methods were used to identify components. Mass chromatograms of three prominent ions in each specified compound were examined.

Identification was based on the appearance of the three peaks, in the correct area ratios, eluting at the retention time of the compound of interest. The background subtracted mass spectra of all significant peaks were also manually interpreted and identification was based on comparisons of the spectra with authentic standards or spectra in the EPA/NIH Mass Spectral Data Base.

SECTION 6

RESULTS AND DISCUSSION

6.1 GENERAL

As discussed earlier, the overall objectives of this study were to determine the effect of Powdered Activated Carbon (PAC) on the removal of trace organics and to determine where PAC should be added to the water treatment system for effective removal of these organics. A bench scale study was designed to provide control of as many variables as possible. The analytical procedures involved some of the latest instrumentation to achieve a high level of sensitivity. EPA provided quality control standards throughout the project to maintain a check on analytical accuracy. Some duplicate samples were analyzed to check the precision of analytical procedures and instruments. The quality control procedures are discussed in Section 6.2.

Trihalomethane values were utilized as one of the key parameters monitored during the project. Summarizing this test:

1. Volatile organic compound analyses were performed on samples which were dechlorinated immediately after the sample was gathered. The sum of these volatile organic compounds present which are trihalomethanes are termed the instantaneous trihalomethane concentration (ITHM).
2. Volatile organic analyses were performed on samples which were incubated in the presence of chlorine for 5 days at pH 10 and a temperature of 85°F (29.4°C). Five days was selected because this length of time approximates the detention time in the distribution system. The sum of these volatile organic compounds present that are trihalomethanes are Terminal Trihalomethane (TTHM).
3. The trihalomethane formation potential (THMFP) is the difference between the total terminal and instantaneous values.

Volatile organic analyses detected and quantified organics in addition to trihalomethanes. Other organics were detected and quantified by the high molecular weight compound analysis. These analyses were utilized to determine which organic compounds (specified for study by EPA) were in the water supply and treated water (See Table 4.1). As a spinoff, organics other than those on the list were also identified. These data are presented in Appendices.

Fluorescence emission and UV absorbance data were developed to evaluate these procedures as potential operational control parameters. It should be noted that the absorbance and fluorescence data were analyzed two different ways as stated in Secton 5.1.4.

6.2 DATA UTILIZATION AND QUALITY CONTROL

Data developed during this project has been utilized in a manner which maximizes the number of conclusive observations within the limits of the accuracy of the information presented.

In some cases, the data allows for rigorous analytical comparisons, while in other cases, the availability of data or the accuracy of the data limits the evaluation to a projection of trends.

Reasons for variability of the data include:

1. Implementation of New Technologies – The present study is one of a limited number of such studies in the country which attempted to monitor trace organics at the ' micro" level concentration. Technology for

measuring at these levels was in the pioneer stages at the onset of this project. Modification of Gas Chromatograph-Mass Spectrometry methodology during the implementation of this subject project is an example of the dynamics of this developing field.

Recent data utilization of TTHM monitoring as an indicator of the potential for carcinogenic compounds is a second example of the embryonic stages of development of the analytical techniques used in this project.

2. Cost and Time Schedule – As a result of the extended period of time and the high cost of completing the analyses established by the approved protocols, it was not feasible to run duplicate analysis of each sample.

Two types of quality control efforts were conducted during the project. EPA's Environmental Monitoring and Support Laboratory (EMSL) sent standards to UNO for TOC and volatile gas chromatograph analyses. The samples were also analyzed by EPA personnel in the Drinking Water Research Division's Organic Control – Chemical Studies Section. After UNO made some modifications in their TOC procedure, the EPA and UNO results were comparable enough to use for trend analysis. The volatile organic standard was analyzed by both labs with adequate results. The six compounds in the standard were chloroform, 1,2-dichloroethane, carbon tetrachloride, bromodichloromethane, dibromochloromethane and bromoform.

The second type of quality control consisted of the analysis of random duplicate samples. Results of the analyses are presented in tables in the appendices. This procedure established the credibility of the particular analytical technique. Because of the limited number of duplicate experiments, certain data have shown inconsistencies. Additionally, because some of the analytical techniques were not precise enough, the data have been used to develop trend analyses.

6.3 PLANT PROFILES AND CHLORINATION STUDIES

The first plant profile was conducted in September, 1978, while the Mississippi River was at a low flow. The second profile was conducted in April 1979 while the river was at its peak flow. Figure 4.2 in Section 4.4 is a schematic of the water treatment system with the eleven sample sites indicated by letters A through K. Data obtained during these experiments may be found in the Appendices as indicated below:

- Temperature, pH, turbidity, UV absorbance, UV absorbance scan, fluorescence and fluorescence scan are presented in Tables A.1 and A.2.
- Total organic carbon data are presented in Tables A.3 and A.4.
- Concentrations of identified volatile organics are presented in Tables A.5 and A.6.
- Concentrations of terminal trihalomethanes are presented in Tables A.7 and A.8.
- Concentrations of high molecular weight compounds and chlorine demand are found in Tables A.9-A.14.
- THM data are presented graphically in Figures 6.1, 6.2 and 6.3.

The trihalomethane bar graphs are a plot of the total THM concentration versus the particular sample. TTHM values were taken from the volatile organic tables. Terminal THM values are depicted on top of each bar. These values were obtained after a 5 day storage at pH 10 and 85°F (29.4°C). The values are also shown in the term THM tables. Bar D in Figure 4.1 is shown as a broken bar because the sample bottle had insufficient chlorine after 5 days.

The above referenced data indicate:

1. Chloroform was by far the predominant trihalomethane.
2. Organic level as measured by TOC generally decreases through the treatment process.
3. Atrazine was the most common high molecular weight compound identified.
4. In both plant profiles, the THMs were reduced by coagulation/sedimentation and remained relatively constant thereafter. TTHM were reduced from 698 µg/L in the raw water to 375 µg/L in the filter effluent (46% removal) in the first plant profile. The second plant profile exhibits values of 701 µg/L raw TTHM, 377 µg/L filter (46% removal).
5. The tap sample taken at UNO should not be used due to possible contamination in the distribution system. Several of the compounds identified were higher in the tap sample than in the plant filtration sample.

6. The HMW compounds remained at approximately the same concentration in the raw and finish waters.
7. Turbidity shows a significant decrease through the treatment process. Absorbance and fluorescence data show a general decrease through the treatment process.

Objective 1 was to develop data to document the occurence of trace organics in the New Orleans water supply and to determine how these organics are changed or removed in the treatment process.

Extensive efforts were made to identify organics at several locations:

- Raw water
- Plant finished water
- Tap (approximately five days from plant finished water)

Additionally data are available at intermediate points in the process.

At the initiation of the project, EPA prepared a list of 37 organic compounds, the presence of which was to be determined. Table 6.1 is a presentation of the trace organic compounds of interest as well as data on those identified in the raw water and treatment plant finished water. As shown in that Table, 15 of the 37 subject compounds were identified at some point in the treatment system in concentrations varying from trace amounts to 160 µg/L.

THM data summarized from all experiments is as follows:

ITHM	RAW	FINISHED	TAP
No. of Samples	5	5	2
Minimum (µg/L)	0	39	134
Maximum (µg/L)	0	147	190
Average (µg/L)	0	101	162
Term THM			
No. of Samples	5	5	2
Minimum (µg/L)	358	160	355
Maximum (µg/L)	701	377	533
Average (µg/L)	586	272	444

The data presented above indicate that raw water regularly contains a trihalomethane protential several fold in excess of 100 ug/L. Because 100 ug/L is the progmulgated maximum limit, if potential is fully converted to the trihalomethane products, the water supply would be significantly out of compliance. However, both plant profiles showed that this potential is not necessarily fully converted to THM. For example, the tap sample in profile number 2 would have a THM concentration of 533 ug/L (as measured by TTHM) but actual THM concentration was only 134 ug/L (as measured by ITHM). Therefore, one potential means of controlling THM is by controlling the reaction whereby precursors are converted to THM.

The two plant profiles indicate that the treatment system as it is presently operated does remove significant amounts of the THM precursors. For example, in the first profile a raw river value of 698 µg/L THM was reduced to 375 µg/L THM after filtration whereas in the second profile a 701 µg/L THM value was reduced to 377 UG/L THM. The majority of precursor removal occurs through the coagulation/sedimentation process.

Profile data indicated that HMW compounds are also removed by the treatment process. Although data through the plant was somewhat erratic, atrazine was reduced by 36 and 39% and phthalate was reduced by 0 and 34% respectively for plant profiles (Tables A.9 and A.10).

Figure 6.3 represents the results of the laboratory chlorination studies conducted during the two plant profiles. The results were inconclusive as to a preferable method of chlorination. The tests were not all that similar to the full scale plant situation.

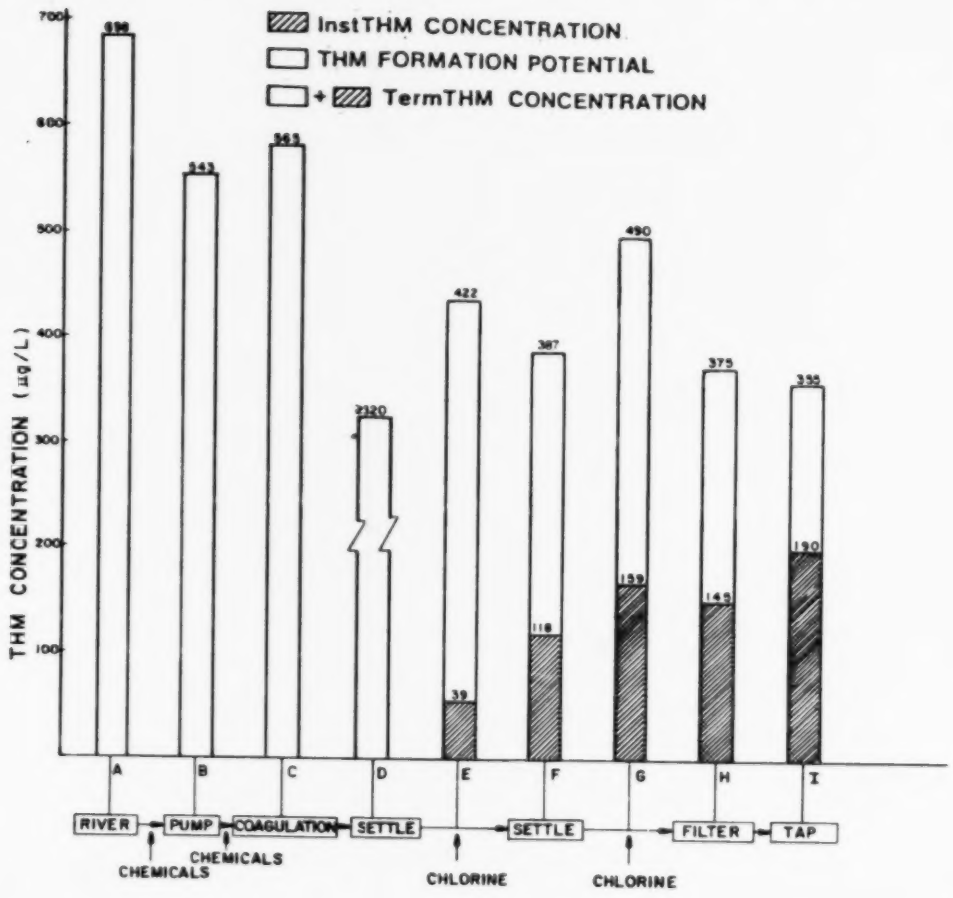

FIGURE 6.1 Results of Trihalomethane Analysis During First Plant Profile – September, 1978

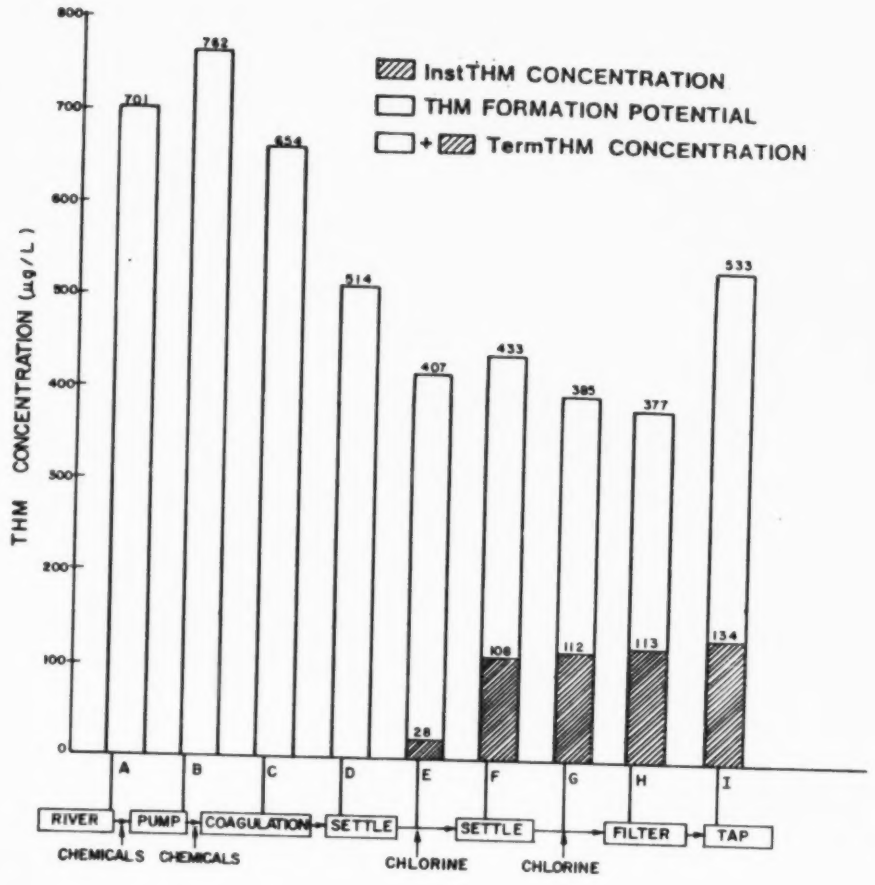

FIGURE 6.2 Results of Trihalomethane Analysis During Second Plant Profile – April, 1979

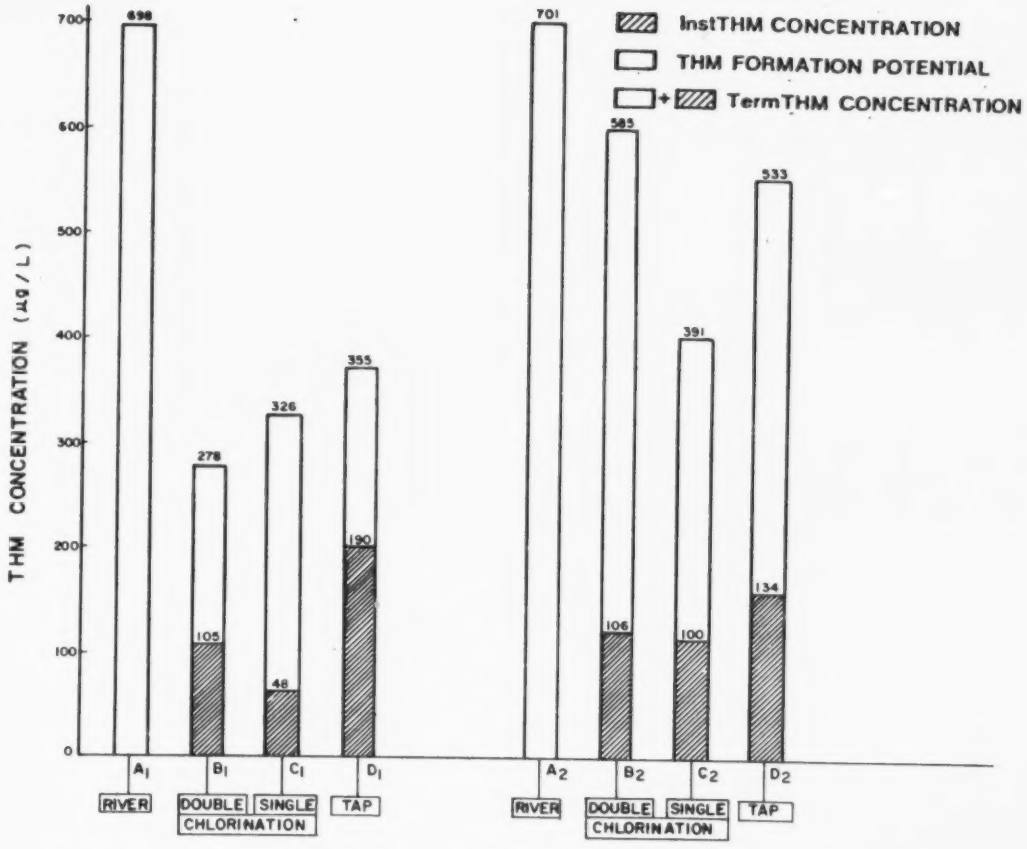

FIGURE 6.3 Results of Trihalomethane Analysis During First and Second Chlorination Study

SEWERAGE AND WATER BOARD

NEW ORLEANS

Number of Times the Trace Organics Were Identified

TABLE 6.1

ORGANIC SUBSTANCES OF INTEREST	Raw Water		Finished Water		Other Plant Locations
	Trace Concentrations	Greater than Trace Concentrations Number (Range)	Trace Concentrations	Greater than Trace Concentrations Number (Range)	Concentration
Atrazine & Diethyl atrazine	0	5 (0.48 - 3.66 µg/L)	0	5 (0.14 - 5.02 µg/L)	
Benzene	1	3 (0.25 - 0.44 µg/L)	1	3 (0.38 - 2.2 µg/L)	
Bis- (2-chloroethyl) ether					
Carbon Tetrachloride					
Chloroform	1	0	0	5 (36.3 - 160 µg/L)	
Bromoform	0	0	0	0	t
Bromodichloromethane	0	0	0	5 (3.1 - 21 µg/L)	(settling/sludge)
Chlordane					
Dibromochloromethane	1	0	3	2 (4.16 - 9.1 µg/L)	
DDE					0.67 µg/L
DDT					(settling)
Dieldrin & Aldrin					
p- dichlorobenzene					
1, 2-dichloroethane	1	3 (0.65 - 1.8 µg/L)	1	3 (0.51 - 1.5 µg/L)	
di- (2 ethylhexyl) phthalate	0	5 (0.26 - 0.58 µg/L)	0	5 (0.30 - 0.55 µg/L)	
2, 4-dichlorophenol					
heptachlor & heptachlor epoxide					
hexachlorobenzene	0	1 (0.12 µg/L)	0	0	
Isophorone					
Nitrobenzene					
Polychlorinated biphenyls					
Fluoranthene	1	2 (0.04 - 0.09 µg/L)	0	1 (0.24 µg/L)	
11, 12-Benzfluoranthene					
3, 4-Benzfluoranthene					0.62 µg/L
1, 12-Benzperylene	0	1 (0.06 µg/L)	0	0	(settling)
3, 4-Benzpyrene					
Indeno (1, 2, 3- cd) Pyrene					
Tetrachloroethane					
1, 2, 4-Trichlorobenzene					
1, 1, 2-trichloroethane					
Toluene	3	1 (0.51 µg/L)	1	3 (0.26 - 0.64 µg/L)	
Vinyl Chloride					
Xylene	1	0	0	1 (0.63 µg/L)	

Note: t = trace amount detected

6.4 PAC SCREENING

PAC screening was conducted in November 1978 with the purpose of selecting a carbon for use in subsequent experiments. The data from the experiments may be found as detailed below and discussed in the following sections:

- Temperature, pH, turbidity, UV absorbance, and fluorescence data are shown in Table B.1.
- The TOC data is shown in Table B.2.
- Concentrations of identified volatile organics are in Table B.3.
- Concentrations of terminal trihalomethanes are in Table B.4.
- Concentrations of the high molecular weight compounds and the chlorine demand data are in Tables B.5 through B.7.
- Figure 6.4 is a plot of the total THM data from the carbon screening.

Four individual PAC samples were analyzed for their applicablility for subsequent testing. They were evaluated based on the data included in Appendix B. Three separate individual evaluations were made by ranking the performance of each carbon at each dosage for each parameter. For example, in Figure 6.4 the four carbons at 5 mg/L dosage were ranked in the order of Amoco, Westvaco, Husky and ICI. The sum of all rankings were utilized to select the preferable carbon. ICI had the greatest number of first place finishes. Figure 6.4 also shows that the ICI PAC at 500 mg/L dosage was the only one which reduced the THMFP to less than 100 ug/L. Results of these evaluations indicated that ICI PAC was preferable for use in evaluating possible treatment modifications for subsequent testing.

The raw water sample taken during the carbon screening contained the following specific organics:

COMPOUND	CONCENTRATION
1,2 Dichloroethane	0.65 µg/L
Toluene	trace
Atrazine	3.66 µg/L
Fluoranthene	0.09 µg/L
Di (2 ethyl hexyl) phthalate	0.26 µg/L

The following is a list of compounds found in the finished water:

COMPOUND	CONCENTRATION
Chloroform	123 µg/L
1,2 Dichloroethane	0.65 µg/L
Bromodichloromethane	20.4 µg/L
Toluene	0.26 µg/L
Dibromochloromethane	4.16 µg/L
Atrazine	5.02 µg/L
Di (2 ethyl hexyl) phthlate	0.26 µg/L

6.5 INVESTIGATIVE STUDY NO. 1

The first investigative study (Section 4.8.1) was conducted in late January, 1979, and involved the addition of ICI powdered activated carbon to raw river water. Data generated during this experiment are presented in the appendices as follows:

- Temperature, Ph, turbidity, UV absorbance, and fluorescence are presented in Table C.1.
- TOC data are presented in Table C.2.
- Concentration of identified volatile organics are presented in Table C.3.
- Concentration of terminal THM are presented in Table C.4.
- Concentration of high molecular weight compounds and chlorine demand are found in Table C.5 through C.7.
- Total THM data are presented graphically in Figure 6.5.

- TOC data is presented graphically in Figure 6.6.
- UV absorbance, UV absorbance scan, fluorescence and fluorescence scan data are presented graphically in Figures 6.7 through 6.10, respectively.

The data presented in the above mentioned tables and figures indicate:

1. Removal efficiency of the PAC raw water (treated sample compared to the stirred control) were as follows:

PAC DOSAGE	PAC REMOVAL EFFICIENCY			
	TOC		TTHM	
	(mg/L)	% Removal[1]	(µg/L)[1]	% Removal
0 (stirred control)	3.7-6.0		225	
5 mg/L	2.4-2.5	50	232	undetermined
50 mg/L	1.4-1.5	70	155	30
500 mg/L	0.2-0.25	95	36	85

[1]Utilizes Average Value

2. Chloroform constituted the following percentage of the terminal trihalomethane:

SAMPLE	% OF CHLOROFORM IN TTHM
Raw River	93
5 mg/L PAC	89
50 mg/L PAC	85
500 mg/L PAC	56
Stirred Control	90
Unstirred Control	90
Finish	90

3. The HMW compounds of atrazine and di (2 ethyl hexyl) phthalate were present in both raw and finished water. With a PAC dosage of 500 mg/L, the atrazine concentration level was 10% less than the stirred control but di (2 ethyl hexyl) phthalate concentrations were higher than the control. (Table C.5)
4. Six volatile organic compounds were present in the finished water and three were present in the raw water (Table C.3). Of the three present in the raw water, PAC reduced both 1,2-dichloroethane and benzene to trace amounts when dosed at 50 mg/L or more. Toluene data were erratic.
5. Removal efficiences (as compared to the stirred control) for the various organic compounds in the terminal THM are presented below. Stirred control values were: chloroform 201.3 ug/L, bromodichloromethane 21.7 ug/L, dibromochloromethane 2.1 ug/L.

PAC DOSAGE (mg/L)	REMOVAL EFFICIENCY		
	Chloroform	Bromodichloromethane	Dibromochloromethane
5	0	0	0
50	35	10	0
500	90	45	0

6. One of the objectives of the study was to determine if the UV absorbance and fluorescence techniques could be used as operational control parameters for an indication of trace organics. Data for all the experiments are listed in the Appendix. Data for this experiment were evaluated as a typical representation. UV absorbance and fluorescence removal trends are shown in the following table.

ITEM	REMOVAL TREND					
	TOC[1] (%)	THM[1] (%)	UV[2] (%)	UV[3] Scan (%)	Flur[2] (%)	Flur[3] Scan (%)
5 mg/L PAC	50	0	0	0	10	20
50 mg/L PAC	70	30	30	0	50	50
500 mg/L PAC	95	85	100	65	95	100

1. Removal efficiency
2. Calculation of removal efficiency =
   [Scale reading (stirred control) – Scale reading (PAC sample)] /Scale reading (stirred control)
3. As 2, above, only area under curve substituted for scale reading.
4. TOC and THM data presented in Item 1.

7. The THM concentration in the raw water sample was recorded as greater than or equal to 199 µg/L because an insufficient amount of chlorine was present in the stored sample.

8. The river and tap water were lower during this study than in the plant profiles. Study No. 1 was conducted between the time period of the two profiles, therefore, the river conditions were different in all cases.

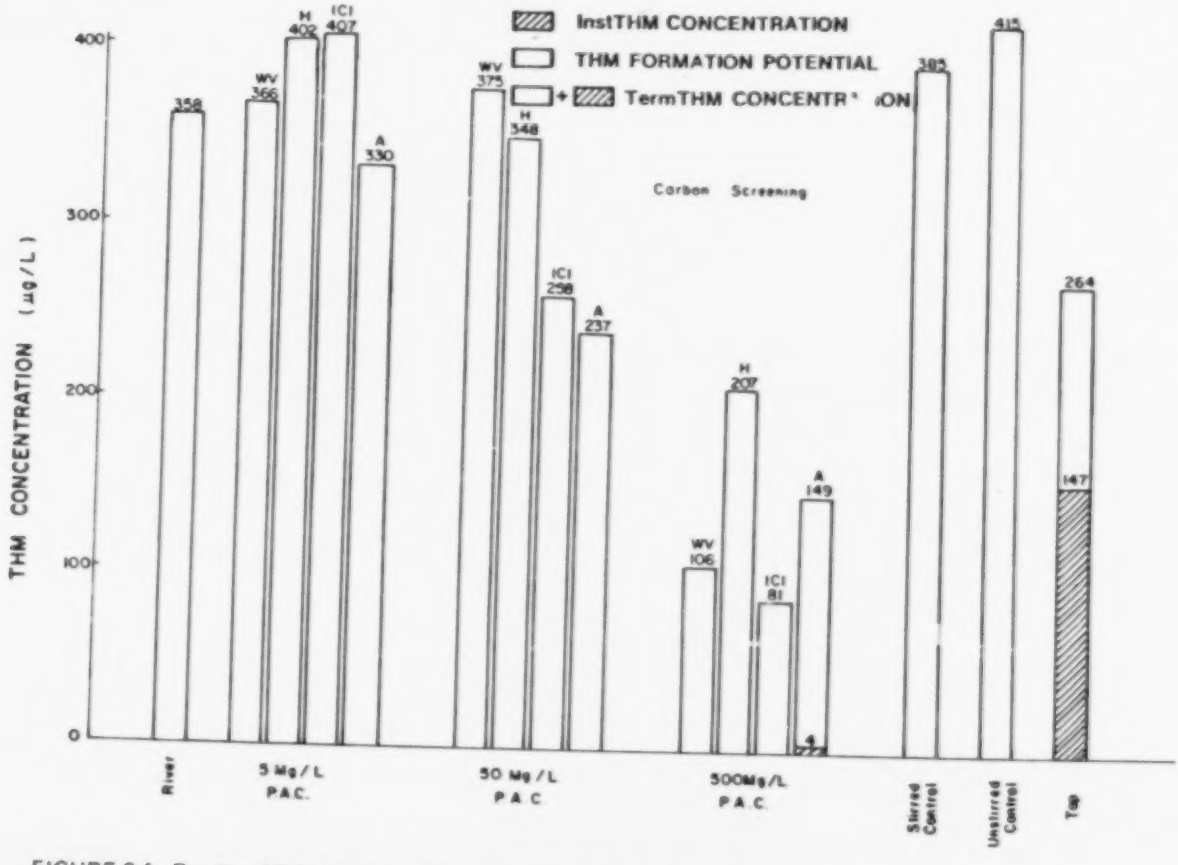

FIGURE 6.4 Results of Trihalomethane Analysis During Carbon Screening

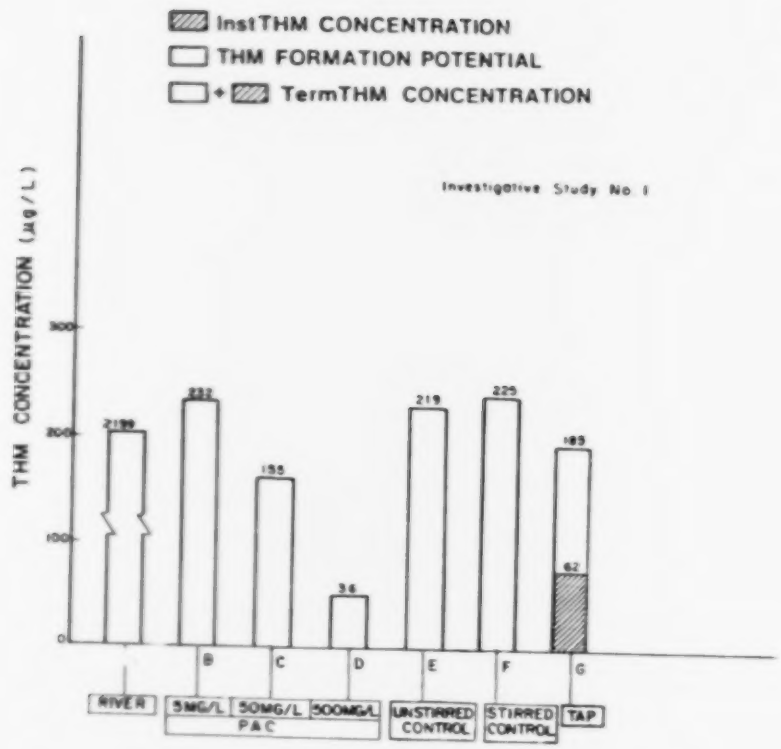

FIGURE 6.5 Results of Trihalomethane Analysis During PAC Addition to Raw Water

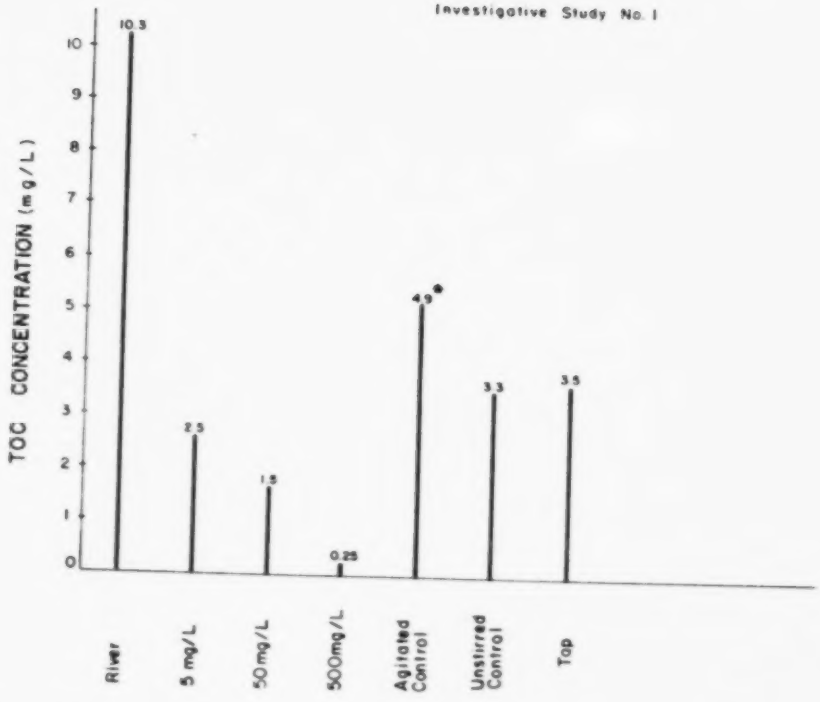

FIGURE 6.6 TOC Removed During PAC Addition to Raw Water
* This value was an average of duplicate samples 6.0 and 3.7.

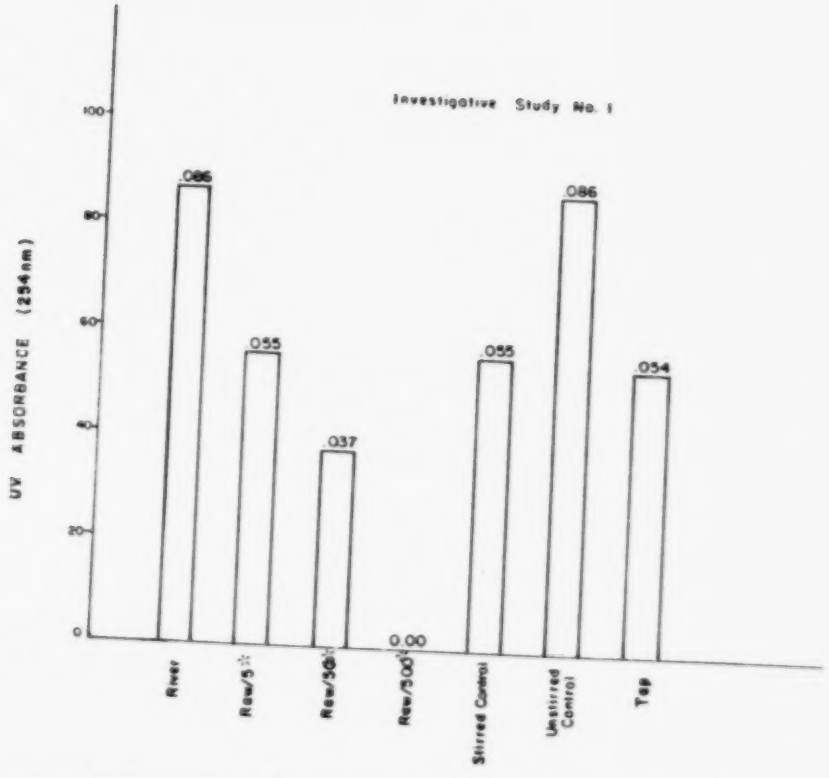

FIGURE 6.7 Organic Removal by PAC Addition to Raw Water as Measured by UV Absorbance at 254 nm

* PAC dosage

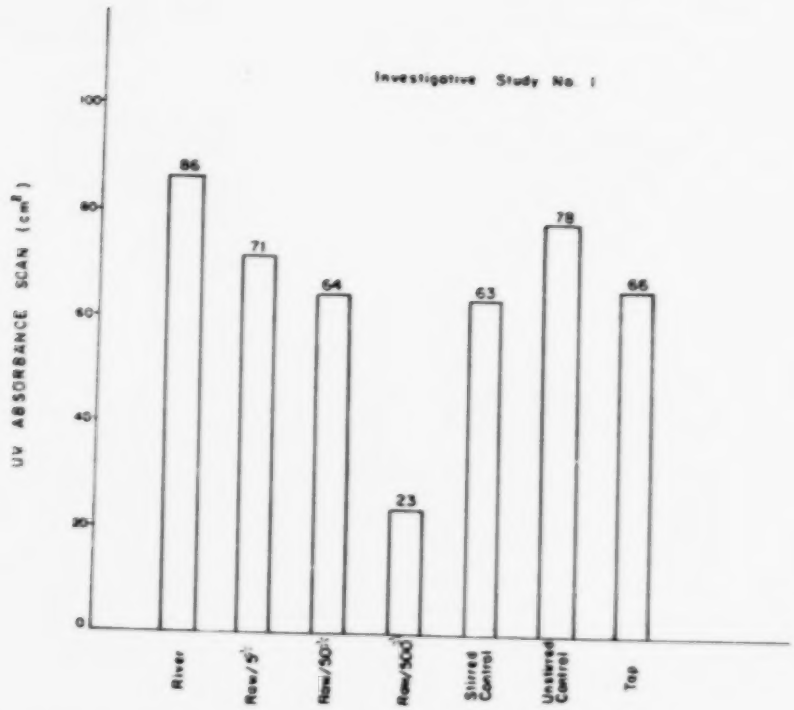

FIGURE 6.8 Organic Removal by PAC Addition to Raw Water as Measured by UV Absorbance Scan From 195-400nm

* PAC dosage

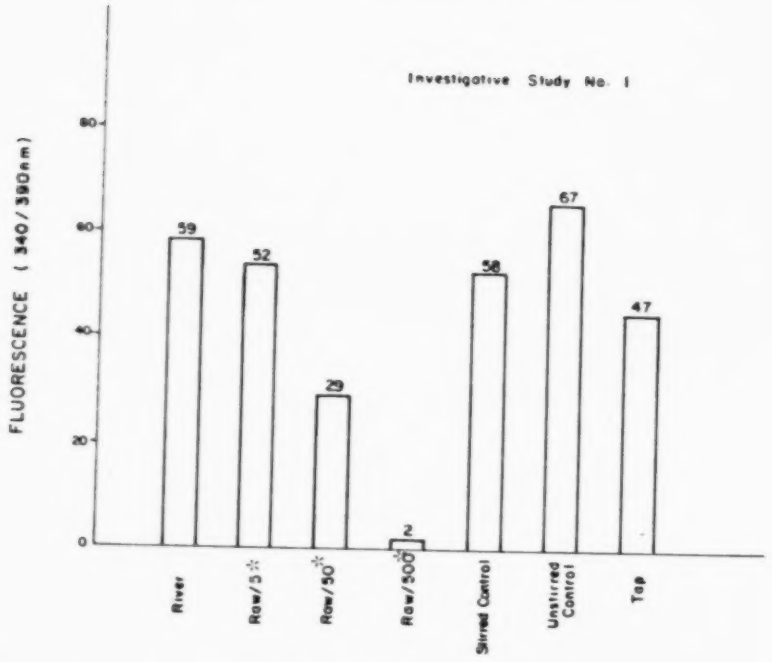

FIGURE 6.9 Organic Removal by PAC Addition to Raw Water as Measured by Fluorescence at Ex340 and Em390

* PAC dosage

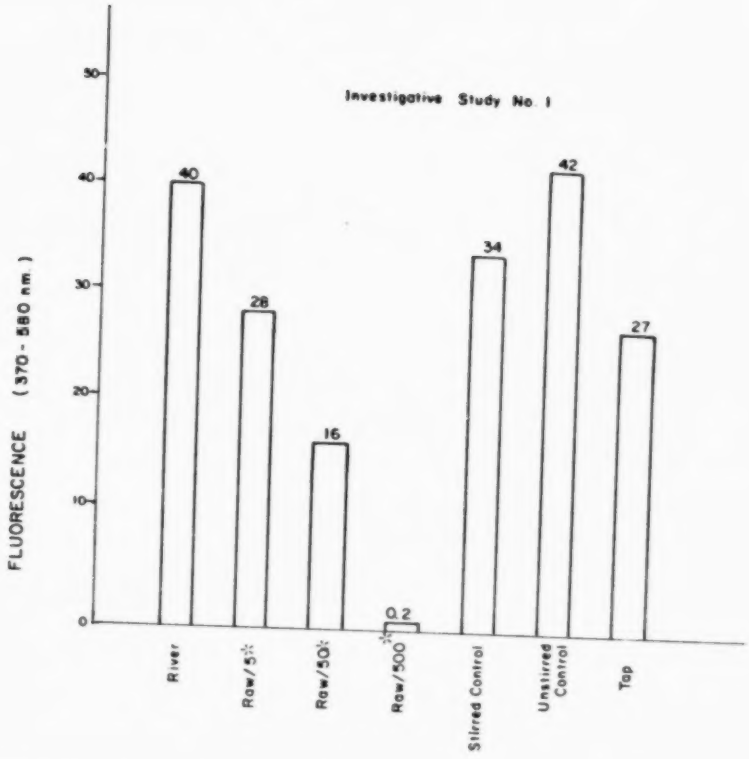

FIGURE 6.10 Organic Removal by PAC Addition to Raw Water as Measured by Fluorescence at Ex310 and Em370-580

* PAC dosage

6.6 INVESTIGATIVE STUDY NO. 2

The second investigative study was conducted in mid-February, 1979. The PAC was added to raw water as in the first study. Half of the study was a repeat of the first study and the second half included a chlorination step before filtration. The repeat of the first study represented a replicate experiment and a side-by-side comparison of chlorinated and non-chlorinated raw water after PAC addition. The data obtained during this experiment are located in the appendices as follows:

- Temperature, pH, turbidity, UV absorbance, and fluorescence data are presented in Table D.1.
- TOC data are presented in Table D.2.
- Concentration of the identified volatile organics are presented in Table D.3.
- Concentration of the terminal trihalomethanes are presented in Table D.4.
- Concentration of the high molecular weight compounds and chlorine demand are presented in Tables D.5 through D.7.
- Total THM data are presented graphically in Figure 6.11.

The data referenced above indicate the following:

1. Removal efficiency of the PAC (treated sample compared to stirred control) are as follows:

REMOVAL EFFICIENCY

PAC DOSAGE	TOC (without Cl_2) (mg/L)	% Removal	TOC (with Cl_2) (mg/L)	% Removal
0 (stirred control)	2.3	0	2.0	0
5 mg/L	3.4	0	2.1	0
50 mg/L	3.7	0	5.5	0
500 mg/L	0.6	75	0.6	70
	TTHM (without Cl_2) (mg/L)	% Removal	TTHM (with Cl_2) (mg/L)	% Removal
0 (stirred control)	204		210	
5 mg/L	154	25	200	5
50 mg/L	126	40	124	40
500 mg/L	31	85	47	80

2. The percentage of TTHM which was chloroform is presented below:

SAMPLE	% CHLOROFORM IN TERMINAL THM Without Cl_2	With Cl_2
Raw River	95	----
5 mg/L PAC	90	90
50 mg/L PAC	80	80
500 mg/L PAC	50	60
Stirred Control	90	90
Unstirred Control	90	----
Finished	90	----

3. The HMW compounds of hexachlorobenzene (1.2 ug/L), atrazine (.048 ug/L), and di (2 ethyl hexyl) phthalate (.33 ug/L) were present in all raw water samples. Additionally, fluoranthene/pyrene was present in the raw water in trace amounts. Removal efficiencies (sample to stirred control were as follows:

SAMPLE	ATRAZINE % Removal	DI (2 ETHYL HEXYL) PHTHALATE % Removal
5 mg/L PAC	0	10
50 mg/L PAC	0	0
500 mg/L PAC	100	10
5 mg/L PAC + Cl_2	0	25
50 mg/L PAC + Cl_2	35	5
500 mg/L PAC + Cl_2	100	50

4. The volatile organic compound data (Table D.3) indicate six of these compounds were present in some samples in trace amounts or greater. The only organic which exhibits consistent data is 1, 2-dichloroethane. PAC dosages of 50 mg/L reduced this organic to trace concentrations.

5. Removal efficiencies (as compared to the stirred control) for the various compounds which contribute to TTHM are as follows for the PAC without chlorine:

PAC DOSAGE (mg/L)	REMOVAL EFFICIENCY					
	Chloroform		Bromodichloromethane		Dibromochloromethane	
	µg/L	% Removal	µg/L	% Removal	µg/L	% Removal
Stirred control	178	–	20	–	6	–
5	136	25	14	30	4	40
50	103	40	17	20	7	0
500	16	90	9	60	6	0

Data are as follows for the PAC with chlorine:

PAC DOSAGE (mg/L)	REMOVAL EFFICIENCY					
	Chloroform		Bromodichloromethane		Dibromochloromethane	
	µg/L	% Removal	µg/L	% Removal	µg/L	% Removal
Stirred control	186	–	19	–	5	–
5	174	10	19	5	7	0
50	102	45	16	20	7	0
500	27	85	12	40	7	0

6. UV and fluorescence data removal trends for the samples without chlorine are as follows:

ITEM	REMOVAL TREND					
	TOC[1] (%)	THM[1] (%)	UV[2] (%)	UV[3] Scan (%)	Flur[2] (%)	Flur[3] Scan (%)
5 mg/L PAC	0	25	0	1	15	10
50 mg/L PAC	0	40	30	0	55	50
500 mg/L PAC	75	85	100	30	100	100

1. Removal efficiency.
2. Calculation of removal efficiency =
   [Scale reading (stirred control) – Scale reading (PAC sample)] /Scale reading (stirred control)
3. As 2, above, only area under curve substituted for scale reading.
4. TOC and THM data presented in Item I.

Those treated with PAC and chlorine exhibited the following data:

ITEM	TOC[1] (%)	THM[1] (%)	REMOVAL TREND UV[2] (%)	UV[3] Scan (%)	Flur[2] (%)	Flur[3] Scan (%)
5 mg/L PAC	0	5	0	0	15	10
50 mg/L PAC	0	40	50	20	55	55
500 mg/L PAC	75	80	95	30	100	100

1. Removal efficiency.
2. Calculation of removal efficiency =
   [Scale reading (stirred control) – Scale reading (PAC sample)] /Scale reading (stirred control)
3. As 2, above, only area under curve substituted for scale reading.
4. TOC and THM data presented in Item 1.

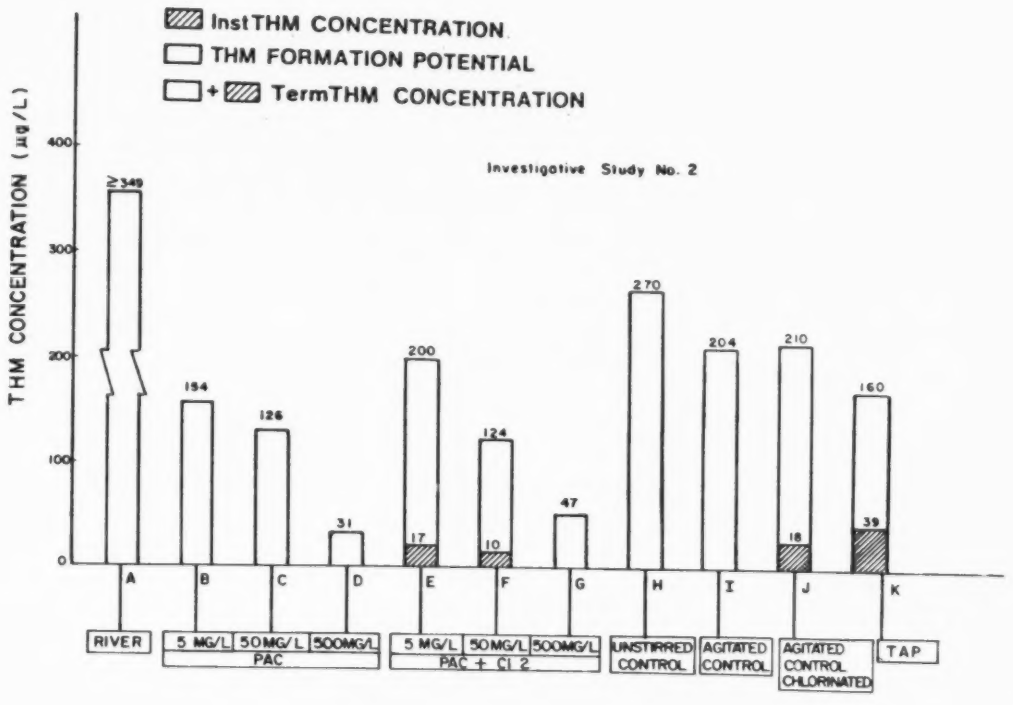

FIGURE 6.11 Results of Trihalomethane Analysis During PAC Addition to Raw Water With and Without Chlorination

6.7 INVESTIGATIVE STUDY NO. 3

Study No. 3 was conducted the day after Study No. 2. The same raw water supply was coagulated and settled in the feed tank and used for the experiment. This was done to limit the variables between Study No. 2 and Study No. 3. Two sets of three reactors were used to compare chlorination versus no chlorination of PAC treated coagulated and settled water. The data obtained from this experiment are presented in the appendices as follows:

- Temperature, pH, turbidity, UV absorbance, and fluorescence data are presented in Table E.1.
- TOC data are presented in Table E.2.
- Concentration of the identified volatile organics are presented in Table E.3.
- Concentration of the terminal trihalomethanes are presented in Table E.4.
- Concentration of the high molecular weight compounds and chlorine demand are presented in Tables E.5 through E.7.
- Total THM data is presented graphically in Figure 6.12.

The data referenced above indicate the following:

1. Removal efficiency of the PAC (treated sample compared to stirred control) are as follows:

REMOVAL EFFICIENCY

PAC DOSAGE	TOC (without Cl_2) (mg/L)	% Removal	TOC (with Cl_2) (mg/L)	% Removal
0 (stirred control)	1.6	–	1.7	–
5 mg/L	1.5	5	1.6	5
50 mg/L	0.8	50	1.0	40
500 mg/L	0.1	95	0.1	95
	TTHM (without Cl_2) (mg/L)	% Removal	TTHM (with Cl_2) (mg/L)	% Removal
0 (stirred control)	337	–	278	–
5 mg/L	354	0	315	0
50 mg/L	165	50	194	30
500 mg/L	57	80	20*	95*

* The river and 500 mg/L PAC samples may be less than actual due to insufficient chlorine in test.

2. The percentage of TTHM which was chloroform is presented below:

SAMPLE	% CHLOROFORM IN TERMINAL THM Without Cl_2	With Cl_2
5 mg/L PAC	90	90
50 mg/L PAC	90	85
500 mg/L PAC	70	80
Stirred Control	95	90
Unstirred Control	95	----

3. The same specified HMW organics were identified in this study as those in Study No. 2 The initial concentrations of atrazine and di(2 ethyl hexyl) phthalate were 0.48 ug/L and 0.33 ug/L respectively. The removal efficiencies (sample to stirred control) were as follows:

SAMPLE	ATRAZINE % Removal	DI (2 ETHYL HEXYL) PHTHALATE % Removal
5 mg/L PAC	65	0
50 mg/L PAC	35	0
500 mg/L PAC	50	0
5 mg/L PAC + Cl_2	60	35
50 mg/L PAC + Cl_2	50	25
500 mg/L PAC + Cl_2	55	0

4. The same six volatile organic compounds were present as in Study No. 2 (Table E.3). The PAC did remove the 1, 2-dichloroethane in a linear relationship. Chloroform also decreased with increasing PAC dosage in the chlorinated reactors.

5. Removal efficiencies (sample compared to stirred control) for the various THM are as follows:

PAC DOSAGE (mg/L)	REMOVAL EFFICIENCY					
	Chloroform		Bromodichloromethane		Dibromochloromethane	
	Initial Conc.	% Removal	Initial Conc.	% Removal	Initial Conc.	% Removal
Stirred control	315	–	17	–	5	–
5	328	0	20	0	6	0
50	146	55	14	20	6	0
500	40	85	10	41	8	0
Stirred control Cl_2	255	–	17	–	6	–
5 + Cl_2	288	0	20	0	7	0
50 + Cl_2	168	35	18	0	8	0
500 + Cl_2	17	95	3	80	t	100

6. The UV absorbance and fluorescence data indicate removal trends as can be seen in the following table:

SAMPLE	REMOVAL TREND (%)					
	TOC[1]	TTHM[1]	UV[2]	UV[3] Scan	Flur[2]	Flur[3] Scan
5 mg/L PAC	5	0	0	0	15	10
50 mg/L PAC	50	50	50	20	50	50
500 mg/L PAC	95	80	100	30	95	95
5 mg/L PAC + Cl_2	5	0	10	5	10	10
50 mg/L PAC + Cl_2	40	30	40	10	55	55
500 mg/L PAC + Cl_2	95	95	90	30	95	95

1. Removal efficiency
2. Calculation of removal efficiency =
   [Scale reading (stirred control) – Scale reading (PAC sample)] /Scale reading (stirred control)
3. As 2, above, only area under curve substituted for scale reading.
4. TOC and THM data presented in Item 1.

Objective 2 was to evaluate the effectiveness of PAC in removing trace organics (both their original and modified forms) and the effect of PAC addition location in the treatment plant upon removal efficiency.

The three major types of data which can be used for a determination of removal efficiency are the volatile organics (other than THMs), the trihalomethanes (precursors) and the HMW compounds (specified). The following table will summarize the data presented in Section 4 and the Appendices. Removal efficiencies are based on comparison to the stirred control.

REMOVAL EFFICIENCY (%)

	VOLATILES[a] Study No. 1			TTHM Study No. 2			HMW[b] Study No. 3		
PAC DOSAGE	1	2[c]	3[c]	1	2[c]	3[c]	1	2[c]	3[c]
5 mg/L	15	45/15	5/10	0	25/5	0/0	10	0/0	65/60
50 mg/L	100	100/100	0/100	30	40/40	50/30	5	0/35	35/50
500 mg/L	100	100/100	100/100	85	85/80	80/95	10	100/100	50/55
Finished water	0	35/15	0/0	20	20/25	50/40	20	5/45	70/65

a. Only 1, 2-dichloroethane was used because data for the other volatiles were erratic.
b. Only atrazine was used because data for the phthalates were erratic.
c. Data from reactors with and without a chlorine dose.

The 5 mg/L PAC dosage provided little or no additional removal efficiency than the full scale plant; the 50 mg/L dosage provided marginal improvement; and, the 500 mg/L PAC dosage provided greater than 80% removal of volatiles and TTHM, and better removal of atrazine.

The PAC was added to the raw water in Study No. 1 with no chlorination step. The second study was a repeat of the first with the addition of a single chlorination step to a portion of the reactors. The third study compared PAC addition after coagulation/sedimentation both with and without a single chlorination step. Evaluation of removal data as compared to the location at which PAC is added indicates no consistent trends. However, if data which is inconsistent with either observation, are eliminated (Volatiles/Study 3/50 mg/L; THM/Study 2/5 mg/L; HMW/Study 2/500 mg/L) it is concluded that PAC addition location has minimal effect on efficiency.

Objective 3 was to evaluate four analytical techniques in as far as their applicability as indicators of trace organics.

The procedures were added to this project's protocol for further investigation. In this section the four absorbance and fluorescence tests are presented along with TOC and TTHM data. No rigid statistical comparisons were made. However, the data for the various tests indicates that the % "removal" shown by each of the four tests generally increases as does the % removal in the TOC and THM tests.

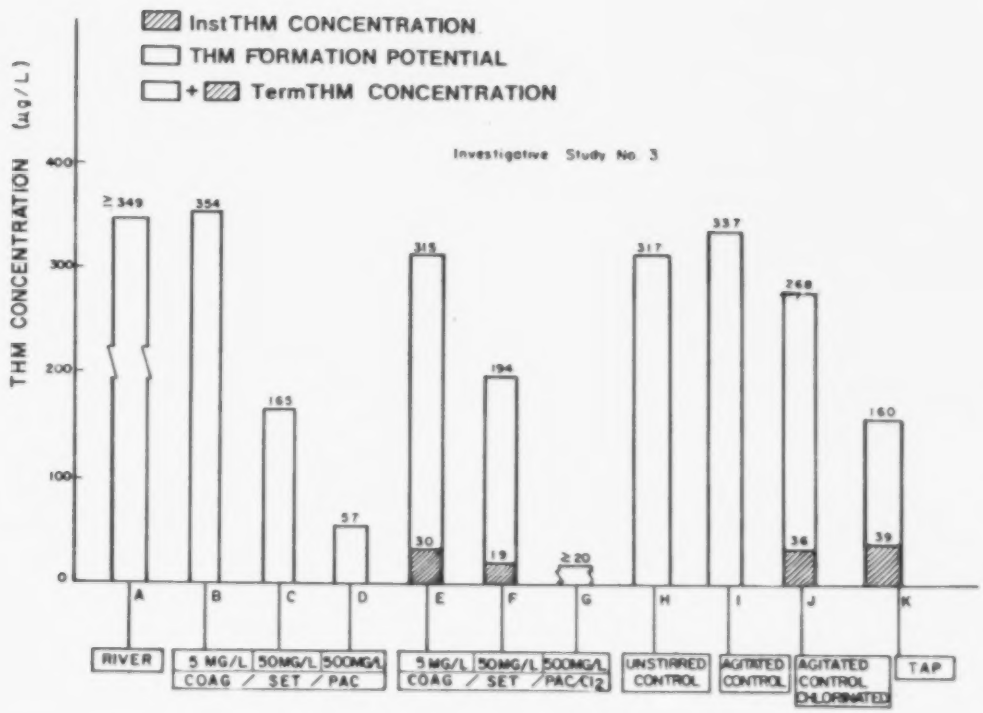

FIGURE 6.12 Results of Trihalomethane Analysis During PAC Addition to Coagulated/Settled Water With and Without Chlorination

APPENDIX A

First and Second Plant Profiles and Chlorination Studies Data

SEWERAGE AND WATER BOARD
New Orleans

TABLE A.1

First Plant Profile and Chlorination Study – September 1978

Sample No.	Location	Temperature °C	pH	Turbidity NTU	UV Absorbance @ 254 nm	UV Scan 190-400	Fluorescence ex 340 nm em 390 nm	Fluorescence scan 370-580 nm
1	Raw River	29.5	7.2	21	0.252	160	21.8	4971
2	Chemicals	29.5	7.4	13	0.154	596	25	4526
3	Coagulation	29.5	9.7	15	0.78	274	18	4600
4	1st settling	29.5	9.75	4.2	0.75	417	18.3	4894
5	1st chlorination	29.5	9.45	2.0	0.70	160	13.5	3953
6	2nd settling	29.5	9.3	2.3	0.33	367	3.0	737
7	2nd chlorination	30.5	9.15	0.9	0.34	153	2.3	584
8	Filtration	30.0	9.2	0.7	0.35	157	2.5	724
9	Tap	29.5	9.25	---	---	137	---	---
10	Prim. sludge	---	---	---	---	---	---	---
11	Backwash	29.5	---	---	---	---	---	---
12	Reactor 1	34	8.85	0.86	---	236	---	---
13	Reactor 2	34	9.35	0.33	---	122	---	---

TABLE A.2

Second Plant Profile and Chlorination Study – April 1979

65	Raw River	14	8.05	69.0	0.093	54.1	77.0	46.2
66	Chemicals	14	7.80	67.0	0.083	55.8	74.5	40.3
67	Coagulation	14	10.30	77.0	0.096	77.7	80.2	42.3
68	1st settling	14	10.48	3.2	0.074	60.3	76.5	38.9
69	1st chlorination	14	10.40	3.2	0.053	45.3	78.0	39.8
70	2nd settling	14	10.05	1.5	0.041	46.3	55.4	26.6
71	2nd chlorination	14	10.20	2.1	0.061	60.8	52.5	27.6
72	Filtration	14	10.20	0.72	0.045	48.4	49.8	23.3
73	Tap	14	10.02	0.47	0.030	43.8	53.0	26.3
74	Prim. sludge	17	10.40	5200	0.125	61.8	135.0	24.5
75	Backwash	14	10.13	0.85	0.039	43.0	56.5	27.1
76	Reactor 1	22	9.80	0.26	0.041	37.0	64.3	31.5
77	Reactor 2	22	10.00	6.64	0.044	40.0	76.5	39.5

SEWERAGE AND WATER BOARD
New Orleans

TABLE A.3

First Plant Profile and Chlorination Study

Sample No.	Location	TOC (mg/L)
1	Raw River	5.5
2	Chemicals	3.5
3	Coagulation	2.1
4	1st settling	6.3
5	1st chlorination	2.8
6	2nd settling	2.7
7	2nd chlorination	4.8
8	Filtration	3.1
9	Tap	2.7
10	Prim. sludge	100
11	Backwash	7.6
12	Reactor 1	2.8
13	Reactor 2	3.0

TABLE A.4

Second Plant Profile and Chlorination Study

Sample No.	Location	TOC (mg/L)
65	Raw River	8.0
66	Chemicals	3.9
67	Coagulation	3.4
68	1st settling	2.2
69	1st chlorination	2.6
70	2nd settling	2.3
71	2nd chlorination	2.1
72	Filtration	2.0
73	Tap	2.2
74	Prim. sludge	20.0
75	Backwash	3.5
76	Reactor 1	2.4
77	Reactor 2	2.1

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TABLE A.5

Volatile Organics (µg/L) (Only Compounds Identified)

First Plant Profile and Chlorination Study

Sample No.	Location	Chloroform	Benzene	Bromo-dichloromethane	Dibromo-chloromethane	Bromoform	Total Inst-THM
1	Raw River	---	0.44	---	---	–	---
2	Chemicals	---	0.40	---	---	–	---
3	Coagulation	---	0.63	---	---	–	---
4	1st settling	---	1.0	---	---	–	---
5	1st chlorination	38.0	0.40	0.45	---	–	39
6	2nd settling	110.0	0.55	4.6	3.0	t	118
7	2nd chlorination	130.0	0.99	23.0	5.5	–	159
8	Filtration	110.0	0.45	29.0	6.1	–	145
9	Tap	160.0	2.2	21.0	9.1	–	190
10	Prim. sludge	t	1.4	---	---	t	---
11	Backwash	120.0	t	24.0	5.7	–	150
12	Chlorination study – two stage chlorination	85.0	t	16.0	4.1	t	105
13	Chlorination study – single stage chlorination	46.0	0.5	1.5	t	t	48

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TABLE A.6

Volatile Organics (µg/L)(Only Compounds Identified)

Second Plant Profile and Chlorination Study

Sample No.	Location	Chloroform	1, 2-Dibromo-ethane	Benzene	Bromodi-chloromethane	Toluene	Xylene	Dibromo-chloromethane	Total Inst-THM
65	Raw River	---	t	0.27	---	0.51	t	t	--
66	Chemicals	---	t	0.25	---	0.22	t	–	--
67	Coagulation	---	t	0.28	---	t	t	–	--
68	1st settling	---	t	0.36	---	0.64	t	–	--
69	1st chlorination	28.0	t	0.55	t	0.75	t	–	28
70	2nd settling	101.3	t	0.70	6.9	0.49	0.47	t	108
71	2nd chlorination	106.0	t	0.32	5.5	0.37	0.39	t	112
72	Filtration	106.4	t	0.20	7.0	0.33	0.38	t	113
73	Tap	124.2	t	0.48	10.0	0.64	0.63	t	134
74	Prim. sludge	96.5	t	0.46	3.4	0.29	0.40	t	100
75	Backwash	135.5	t	0.68	10.8	0.34	0.53	t	146
76	Chlorination study – two stage chlorination	96.6	t	t	9.0	0.21	0.33	t	106
77	Chlorination study – single stage chlorination	97.7	t	0.37	2.5	0.43	0.29	t	100

SEWERAGE AND WATER BOARD
New Orleans

TABLE A.7

Terminal THM (µg/L) (Only Compounds Identified)

First Plant Profile and Chlorination Study

Sample No.	Location	Chloroform	Bromodichloromethane	Dibromochloromethane	Bromoform	Total
1	Raw River	640	31	7.8	19.0	698
2	Chemicals	490	38	6.0	9.1	543
3	Coagulation	520	28	10.0	6.8	565
4	1st settling	300	14	6.4	t	320*
5	1st chlorination	380	35	6.9	t	422
6	2nd settling	360	21	5.9	---	387
7	2nd chlorination	470	14	6.4	t	490
8	Filtration	360	8.8	5.9	---	375
9	Tap	340	9.0	6.1	---	355
10	Prim. sludge	--	---	---	---	---
11	Backwash	--	---	---	---	---
12	Chlorination study – two stage chlorination	270	5.2	3.4	---	278
13	Chlorination study – single stage chlorination	300	20	6.5	---	326

* This value may be less than actual due to insufficient chlorine in the test (See Table A.13).

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TABLE A.8

Terminal THM (µg/L) (Only Compounds Identified)

Second Plant Profile and Chlorination Study

Sample No.	Location	Chloroform	Bromodichloromethane	Dibromochloromethane	Total
65	Raw River	676.6	24.8		
66	Chemicals	734.3	27.7	t	701
67	Coagulation	628.3	25.7	t	762
68	1st settling	483.9	26.0	t	654
69	1st chlorination	381.5	20.6	4.2	514
70	2nd settling	406.4	20.8	4.9	407
71	2nd chlorination	359.5	20.5	6.1	433
72	Filtration	349.8	22.3	4.8	385
73	Tap	502.4	25.7	4.7	377
74	Prim. sludge	---	---	4.4	533
75	Backwash	---	---	--	--
76	Chlorination study – two stage chlorination	560.6	24.0	--	--
77	Chlorination study – single stage chlorination	364.6	20.5	t	585
				5.9	391

SEWERAGE AND WATER BOARD
New Orleans

TABLE A.9

Specified High Molecular Weight Compounds

Only Compounds Identified (μg/L)

First Plant Profile and Chlorination Study

Sample No.	Location	Atrazine	Fluoranthene	DDE	Benzo (a) Pyrene	1, 12-benzperylene	Di (2 ethyl hexyl) Phthalate
1	Raw River	1.36	---	---	–	---	0.43
2	Chemicals	1.54	0.34	---	t	---	0.45
3	Coagulation	1.41	0.43	---	t	0.54	0.54
4	1st settling	1.31	0.55	0.67	t	0.62	0.52
5	1st chlorination	1.47	---	---	t	---	0.63
6	2nd settling	0.93	---	---	–	---	22.10
7	2nd chlorination	0.80	---	---	–	---	0.39
8	Filtration	0.87	---	---	–	---	0.48
9	Tap	0.66	0.24	---	–	---	0.35
10	Prim. sludge	1.57	t	---	t	---	0.26
11	Backwash	1.18	---	---	–	---	0.32
12	Chlorination study – two stage chlorination	1.57	---	---	–	---	0.42
13	Chlorination study – single stage chlorination	0.36	---	---	–	---	0.43

SEWERAGE AND WATER BOARD
New Orleans

TABLE A.10

Specified High Molecular Weight Compounds

Only Compounds Identified (μg/L)

Second Plant Profile and Chlorination Study

Sample No.	Location	Atrazine	Fluoranthene/Pyrene	Benzo (a) Pyrene	Di (2 ethyl hexyl) Phthalate
65	Raw River	0.67	–/0.04	0.06	0.44
66	Chemicals	0.62	–/0.08	---	---
67	Coagulation	0.34	--	---	0.28
68	1st settling	0.46	--	---	0.43
69	1st chlorination	0.52	--	---	0.28
70	2nd settling	0.42	--	---	0.24
71	2nd chlorination	0.41	--	---	0.38
72	Filtration	0.41	--	---	0.29
73	Tap	0.39	--	---	0.48
74	Prim. sludge	0.34	--	---	0.19
75	Backwash	0.35	--	---	0.31
76	Chlorination study – two stage chlorination	0.46	--	---	0.36
77	Chlorination study – single stage chlorination	0.37	--	---	0.40

TABLE A.11

First Plant Profile and Chlorination Study

High Molecular Weight Compounds in Sewerage and Water Board Study (µg/L)

(not specified for analysis in Sewerage and Water Board Study)

	Raw Water	Chemicals	Coagulation	1st Settling	1st Chlorination	2nd Settling	2nd Chlorination	Filtration	Tap	Prim. Sludge	Backwash	2-Stage Chlorination	1-Stage Chlorination
N-undecane	0.24	0.23	0.24	0.24	0.23	0.17	0.18	t	0.21	0.25	0.20	0.16	0.16
Naphthalene	0.17	0.19	0.17	0.16	0.14	0.10	0.11	0.03	0.16	0.03	0.15	0.12	0.11
N-dodecane	0.13	0.13	0.12	0.12	0.11	0.09	0.09	0.03	0.10	0.03	0.10	0.09	0.08
Methylnaphthalene	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.03	0.10	0.03	0.03	0.03
Unknown	0.02	0.02	0.01	0.02	0.01	0.01	t	t	0.01	11.5	0.01	0.02	0.03
Unknown	0.06	0.06	0.06	0.08	0.05	0.06	0.03	0.03	0.04	0.03	0.04	0.05	0.08
Unknown	0.08	0.08	0.08	0.02	0.08	0.08	0.05	0.05	0.07	0.11	0.08	0.07	0.07
Biphenyl	0.04	0.03	0.03	0.04	0.03	0.02	0.02	0.02	0.03	0.05	0.03	0.05	0.06
2-methyl-4-tert-butyl-thiophenol (tent.)	0.16	0.09	0.07	0.12	0.06	0.06	0.03	0.07	0.04	0.05	0.05	0.12	0.29
4-methyl, 2, 6-di-tert-butyl phenol (BHT)	0.07	0.07	0.05	0.05	0.05	0.04	0.04	0.05	0.03	0.10	0.03	0.06	0.07
Unknown	0.19	0.16	0.13	0.19	0.16	0.46	0.10	0.13	0.11	0.27	0.15	0.95	1.79
Diethyl phthalate	0.16	0.18	0.20	0.84	0.17	0.20	0.10	0.20	0.21	0.15	0.16	0.34	0.51
Unknown hydrocarbon	0.05	0.05	0.03	0.06	0.03	0.10	0.05	0.03	0.03	0.38	0.15	0.02	0.04
Butyl phthalate isomer	0.29	0.19	0.08	0.38	0.26	1.23	0.44	0.39	0.24	0.26	0.39	0.31	0.42
Unknown	0.09	0.05	0.04	0.08	0.06	0.18	0.08	0.08	0.05	0.21	0.09	0.05	0.08
Butyl phthalate isomer	0.14	0.12	0.10	0.11	0.11	0.07	0.06	0.06	0.08	0.14	0.13	0.12	0.13
Unknown phthalate isomer	0.30	0.37	0.42	0.37	0.28	0.43	0.16	0.28	0.33	1.34	0.38	0.47	0.70
Hydrocarbon	0.06	0.04	0.04	0.11	0.05	0.13	0.06	0.06	0.03	0.19	0.07	0.06	0.08
Unknown phthalate isomer	0.79	0.44	0.21	0.14	0.49	0.58	0.21	0.45	0.19	0.17	0.18	0.39	0.24
Unknown olefin	0.30	0.61	0.63	0.73	0.61	0.99	0.61	1.35	0.93	0.76	0.78	0.70	0.66

TABLE A.12

Second Plant Profile and Chlorination Study

High Molecular Weight Compounds in A2-B2 Sewerage and Water Board Study (non specified for analysis)

(concentrations in µg/L)

Compound	Raw Water *	Chemicals *	Coagulation *	1st Settling *	1st Chlorination *	2nd Settling *	2nd Chlorination *	Filtration *	Tap *	Prim. Sludge *	Backwash *	2-Stage Chlorination *	1-Stage Chlorination *
TOTAL	16.79	18.20	8.35	7.66	10.15	7.50	8.74	8.72	10.2	8.07	10.20	11.37	13.22
Unknown phthalate	0.29	0.39	0.23	0.15	0.20	0.19	0.19	0.19	0.21	0.15	0.27	0.27	0.49
N-octadecane	0.09	0.06	0.05	0.03	0.07	0.04	0.06	0.04	0.05	0.04	0.05	0.04	0.05
Unknown phthalate	0.16	0.20	0.04	0.04	0.14	0.14	0.04	0.05	0.13	0.14	0.54	0.91	0.15
Unknown phthalate	0.66	0.70	0.36	0.44	0.40	0.42	0.33	0.51	0.33	0.25	0.50	0.49	0.57
N-eicosane	0.17	0.12	0.07	0.07	0.09	0.06	0.10	0.07	0.09	0.05	0.08	0.09	0.09
Unknown olefin	3.98	1.37	1.19	0.74	2.03	1.14	1.80	1.48	2.32	0.99	1.63	1.93	2.05
N-heneicosane	0.11	0.09	0.05	0.05	0.06	0.05	0.05	0.05	0.06	0.04	0.06	0.05	0.06
N-docosane	0.09	0.09	0.04	0.03	0.06	0.04	0.05	0.04	0.05	0.04	0.05	0.04	0.05
N-tricosane	0.12	0.19	0.10	0.10	0.07	0.10	0.06	0.07	0.08	0.06	0.09	0.08	0.11
Unknown phthalate	0.28	0.39	0.19	0.27	0.17	0.18	0.29	0.21	0.19	0.17	0.29	0.40	0.53
N-tetracosane	0.13	0.28	0.10	0.16	0.10	0.10	0.10	0.09	0.10	0.08	0.12	0.11	0.12
N-pentacosane	0.11	0.16	0.07	0.06	0.07	0.06	0.07	0.05	0.06	0.05	0.08	0.07	0.07
N-hexacosane	0.08	0.22	0.04	0.04	0.04	0.04	0.06	0.07	0.06	0.05	0.06	0.04	0.09
N-heptacosane	0.07	0.20	0.02	t	0.03	0.03	0.03	0.03	0.03	0.05	0.04	0.03	0.04
N-octacosane	0.08	0.28	0.04	t	t	0.02	0.03	0.09	0.03	0.05	0.03	0.03	0.03
Squalene	0.33	1.19	0.34	0.42	0.65	0.47	0.33	0.31	0.48	0.19	0.44	0.51	0.82
N-nonacosane	0.11	0.40	t	t	0.03	0.03	0.03	0.03	0.03	0.07	0.05	0.04	0.05
N-triacontane	0.10	0.48	0.02	t	t	t	0.03	0.02	0.03	0.10	0.04	0.05	0.05

* Verified by M.S.

TABLE A.13

First Plant Profile and Chlorination Study

Chlorine Demand

Sample No.	Location	Free Chlorine mg/L	Free Chlorine Dosed To mg/L	Final Free Chlorine mg/L	Free Chlorine Demand mg/L
1	Raw Water	0.00	19.00	7.85	11.85
2	Chemicals	0.00	19.00	6.95	12.05
3	Coagulation	0.00	19.00	8.89	10.11
4	1st settling	0.00	8.00	0.17	7.83
5	1st chlorination	4.55	8.00	3.15	4.85
6	2nd settling	0.00	8.00	2.78	5.22
7	2nd chlorination	2.00	8.00	3.47	4.53
8	Filtration	0.73	8.00	2.84	5.16
9	Tap	0.73	8.00	5.21	2.79
12	2-stage chlorination	8.90	8.90	3.96	4.94
13	1-stage chlorination	1.82	8.00	3.56	4.44

TABLE A.14

Second Plant Profile and Chlorination Study

Chlorine Demand

Sample No.	Location	Pre-Dose Cl_2 mg/L	Added Free Cl_2 mg/L	Total Free Cl_2 At Start of Incubation (By Addition) mg/L	Final Free Cl_2 At End of Incubation mg/L	5-Day Free Cl_2 Demand mg/L
65	Raw Water	———	25.00	25.00	3.26	21.74
66	Chemicals	———	25.00	25.00	2.32	22.68
67	Coagulation	———	25.00	25.00	2.30	22.70
68	1st settling	———	25.00	25.00	12.00	13.00
69	1st chlorination	1.19	8.81	10.00	3.34	6.66
70	2nd settling	0.25	9.75	10.00	4.00	6.00
71	2nd chlorination	1.04	8.96	10.00	5.28	4.72
72	Filtration	0.94	9.06	10.00	4.22	5.78
73	Tap	0.30	9.70	10.00	5.16	4.84
76	2-stage chlorination	4.92	10.08	15.00	7.94	7.06
77	1-stage chlorination	1.20	13.80	15.00	7.64	7.36
78	Mille-Q Blank	5.48	9.52	15.00	13.66	1.34
79	Mille-Q Blank w/o chlorine	———	15.00	15.00	12.94	2.06

APPENDIX B

Carbon Screening Data

SEWERAGE AND WATER BOARD
New Orleans

TABLE B.1

Carbon Screening – November 1978

Sample No.	Description	Temperature °C	pH	Turbidity NTU	UV Absorbance @ 254 nm	UV Scan 190-400 nm	Fluorescence ex 340 nm em 390 nm	Fluorescence scan 370-580 nm
18	Raw River	–	7.8	21	0.130	1284	89.1	1348
19	Finish	23	9.42	---	---	---	---	---
20	WV - 5	–	9.59	0.58	0.108	906	83.8	4144
21	WV - 50	–	9.6	0.52	0.110	770	67.5	2871
22	WV - 500	–	9.65	0.22	0.053	320	18.9	638
23	ICI - 5	–	9.67	0.19	0.112	1012	78.4	3840
24	ICI - 50	–	9.60	0.19	0.089	700	48.3	2226
25	ICI - 500	-	9.58	0.16	0.052	303	16.0	544
26	H - 5	–	9.96	1.3	0.119	1011	81.5	4347
27	H - 50	–	10.05	0.29	0.105	868	63.5	3183
28	H - 500	–	10.05	0.21	0.071	477	29.0	1374
29	A - 5	–	10.10	0.31	0.112	910	75.5	3869
30	A - 50	–	10.05	0.18	0.093	668	46.0	2200
31	A - 500	–	9.85	0.21	0.066	372	21.5	1012
32	Stirred control	–	9.55	---	0.117	889	89.1	4417
33	Unstirred control	–	9.55	---	0.122	1016	90.0	4930

SEWERAGE AND WATER BOARD
New Orleans

TABLE B.2

Carbon Screening

Sample No.	Location	TOC (mg/L)
18	Raw River	4.8
19	Finish	5.1
20	WV + 5 PAC	7.3
21	WV + 50 PAC	3.5
22	WV + 500 PAC	1.7
23	ICI + 5 PAC	6.0
24	ICI + 50 PAC	1.6
25	ICI + 500 PAC	6.3
26	H + 5 PAC	3.6
27	H + 50 PAC	2.0
28	H + 500 PAC	2.5
29	A + 5 PAC	3.3
30	A + 50 PAC	3.6
31	A + 500 PAC	1.1
32	Stirred control	2.7
33	Unstirred control	2.8

SEWERAGE AND WATER BOARD
New Orleans

TABLE B.3

Volatile Organics (µg/L)(Only Compounds Identified)

Carbon Screening

Sample No.	Location	Chloroform	1, 2 Dichloro-ethane	Bromodi-chloroethane	Toluene	Dibromo-chloromethane	Total Inst-THM
18	Raw River	---	0.65	---	t	---	--
19	Finish	123	0.51	20.4	0.26	4.16	147
20	WV - 5 PAC	t	t	---	t	---	--
21	WV - 50 PAC	---	t	---	t	---	--
22	WV - 500 PAC	---	---	---	t	---	--
23	ICI - 5 PAC	t	t	---	t	---	--
24	ICI - 50 PAC	t	---	---	t	---	--
25	ICI - 500 PAC	---	---	---	0.27	---	--
26	H - 5 PAC	t	t	---	t	---	--
27	H - 50 PAC	---	---	---	t	---	--
28	H - 500 PAC	t	---	---	t	---	--
29	A - 5 PAC	t	t	---	t	---	--
30	A - 50 PAC	---	---	---	0.29	---	--
31	A - 500 PAC	3.76	---	---	t	---	4
32	Stirred control	t	0.62	---	t	---	--
33	Unstirred control	---	0.61	---	t	---	--

SEWERAGE AND WATER BOARD
New Orleans

TABLE B.4

Terminal THM (µg/L)(Only Compounds Identified)

Carbon Screening

Sample No.	Location	Chloroform	Bromodichloromethane	Dibromochloromethane	Bromoform	Total
18	Raw River	331/308*	28.4/26.4*	5.20/5.09*	5.47/5.61*	358
19	Finish	239	19.8	5.06	t	264
20	WV + 5 PAC	328	31.7	5.76	t	366
21	WV + 50 PAC	333	35.4	6.67	t	375
22	WV + 500 PAC	75.2	22.0	8.90	t	106
23	ICI + 5 PAC	362	36.4	8.63	t	407
24	ICI + 50 PAC	220	31.0	7.14	t	258
25	ICI + 500 PAC	46.3/52.9*	20.8/22.1*	9.11/10.6*	t	81
26	H + 5 PAC	357	38.8	5.79	t	402
27	H + 50 PAC	303	38.1	6.52	t	348
28	H + 500 PAC	167	30.8	8.84	t	207
29	A + 5 PAC	287	36.8	5.85	t	330
30	A + 50 PAC	197	32.1	7.54	t	237
31	A + 500 PAC	106	29.1	9.97	t	145
32	Stirred control	345	34.8	5.61	t	385
33	Unstirred control	372	36.1	6.71	t	415

* Duplicate samples were run as part of a quality control check.

SEWERAGE AND WATER BOARD
New Orleans

TABLE B.5

Specified High Molecular Weight Compounds

Only Compounds Identified (µg/L)

Carbon Screening

Sample No.	Location	Atrazine	Fluoranthene	Di (2 ethyl hexyl) Phthalate
18	Raw River	3.66	0.09	0.26
19	Finish	5.02	---	0.30
20	Westvaco - 5 PAC	2.25	---	0.33
21	Westvaco - 50 PAC	3.45	---	0.70
22	Westvaco - 500 PAC	2.40	---	0.68
23	ICI - 5 PAC	1.76	---	0.26
24	ICI - 50 PAC	1.81	---	0.51
25	ICI - 500 PAC	1.20	---	0.42
26	Husky - 5 PAC	1.19	---	0.58
27	Husky - 50 PAC	3.59	---	0.59
28	Husky - 500 PAC	1.79	---	0.44
29	Amoco - 5 PAC	1.60	---	0.75
30	Amoco - 50 PAC	1.57	---	0.33
31	Amoco - 500 PAC	1.33	---	0.33
32	Agitated control	1.42	---	0.62
33	Unagitated control	2.07	---	0.60

TABLE B.6

High Molecular Weight Compounds in Sewerage and Water Board Study

(not specified for analysis in Sewerage and Water Board Study)

(Concentration in µg/L)

	Carbon Screening															
	Raw Water *	Finish *	WV - 5 *	WV - 50	WV - 500	ICI - 5 *	ICI - 50 **	ICI - 500	H - 5 *	H - 50	H - 500	A - 5 *	A - 50	A - 500	Stirred Control	Unstirred Control
TOTAL	8.33	9.33	16.21	30.01	21.25	15.79	18.33	7.69	13.71	12.39	23.92	12.57	13.62	13.57	27.25	21.68
Unknown	0.05	0.06	0.17	0.40	0.26	0.20	0.23	0.13	0.14	0.17	0.34	0.13	0.17	0.12	0.51	0.28
Unknown	0.06	0.06	0.12	0.24	0.16	0.13	0.29	0.10	0.12	0.15	0.24	0.11	0.13	0.11	0.29	0.17
2, 6-Di-tert.-butyl-4 methyl phenol (BHT) (tent.)	0.03	0.09	1.01	2.60	0.15	1.3	1.32	0.93	1.43	1.44	2.57	1.07	1.11	1.13	1.42	1.26
Unknown phthalate	0.68	0.56	4.98	13.64	4.64	3.40	6.43	2.55	4.91	3.40	9.84	2.99	4.38	3.67	12.1	6.62
Unknown	0.19	0.35	0.28	0.50	3.26	3.82	0.48	0.23	0.43	0.45	0.53	0.32	0.27	0.31	0.59	0.32
Phenanthrene	0.19	---	0.50	0.90	0.58	0.55	---	0.06	0.44	---	0.79	0.45	0.45	0.46	0.66	0.37
Unknown phthalate	0.07	0.06	1.09	0.46	0.90	0.28	0.86	0.21	0.70	0.78	1.89	0.35	0.92	2.08	0.54	1.96
Unknown phthalate	0.48	0.68	0.30	0.67	0.31	0.25	2.10	0.10	0.46	0.22	0.26	0.35	0.14	0.20	0.24	0.24
Unknown	0.25	0.15	0.31	0.35	0.20	0.26	0.19	0.19	0.40	0.21	0.35	0.23	0.14	0.15	0.55	0.42
Unknown	0.87	0.59	1.39	1.23	1.12	0.82	0.96	0.36	0.66	0.81	1.16	0.77	0.61	1.00	1.06	0.82
Unknown phthalate	1.54	1.87	1.40	2.38	1.52	1.20	---	0.16	0.87	0.96	1.51	1.48	0.68	0.97	1.08	1.15
Unknown	0.61	0.59	0.44	0.65	0.63	0.33	---	---	0.27	0.31	0.45	0.44	0.26	0.31	0.52	0.39
Unknown	0.51	0.60	0.45	0.81	0.31	0.30	---	---	0.23	0.19	0.29	0.49	0.12	0.20	0.34	0.31
Unknown phthalate	0.19	0.18	0.45	0.38	0.90	0.31	0.34	0.14	0.27	0.26	0.21	0.19	0.13	0.17	0.38	0.26
Squalene	0.91	1.07	1.10	0.78	2.00	0.81	1.44	0.80	0.34	0.66	0.96	1.24	0.84	0.96	1.49	1.29

* Verified by M.S.

** Quantitation based on 725 ml of sample.

TABLE B-7

Carbon Screening – Chlorine Demand

Sample No.	Description	Free Chlorine (mg/L)	Free Chlorine Dosed To: (mg/L)	Final Free Chlorine (mg/L)	Free Chlorine Demand (mg/L)
18	Raw Water	3.39	15	3.39	11.61
19	Finish	3.03	8	3.03	4.97
20	WV - 5	4.37	15	4.37	10.63
21	WV - 50	4.81	15	4.81	10.19
22	WV - 500	8.09	15	8.09	6.91
23	ICI - 5	4.05	15	4.05	10.95
24	ICI - 50	5.70	15	5.70	9.30
25	ICI - 500	7.42	15	7.42	7.58
26	H - 5	3.22	15	3.22	11.78
27	H - 50	4.82	15	4.82	10.18
28	H - 500	8.12	15	8.12	6.88
29	A - 5	4.90	15	4.9	10.10
30	A - 50	6.14	15	6.14	8.86
31	A - 500	5.64	15	5.64	9.36
32	Stirred control	4.21	15	4.21	10.79
33	Unstirred control	2.06	15	2.06	12.94

APPENDIX C

Investigative Study No. 1 Data

SEWERAGE AND WATER BOARD
New Orleans

TABLE C.1

Investigative Study No. 1 – January, 1979

Sample No.	Description	Temperature °C	pH	Turbidity NTU	UV Absorbance @ 254 nm	UV Scan 190-400 nm	Fluorescence ex 340 nm em 390 nm	Fluorescence scan 370-580 nm
34	Raw River	5	7.85	290	0.086	85.6	58.8	39.8
35	5 mg/L PAC	22	11.25	4.8	0.055	71.02	52.4	28.4
36	50 mg/L PAC	22	11.15	0.17	0.037	64.07	29.2	16.1
37	500 mg/L PAC	22	11.05	0.08	0.0	23.12	2.3	0.2
38	Stirred control	22	11.15	5.4	0.055	62.92	57.9	33.5
39	Unstirred control	22	7.80	14.0	0.086	77.47	67.0	41.8
40	Finish	5	11.10	0.46	0.054	65.77	46.5	26.7
41	Mille-Q stirred	22	5.20	0.12	0.003	1.27	0	0.4 - 3.1
42	Mille-Q & 5 PAC	22	5.60	0.11	0.0	0.67	1.4	0.1
43	Raw & 5 PAC (Water washed filter)	22	11.35	0.14	0.055	70.3	50.8	30.0
44	Raw & 5 PAC (Acid washed filter)	22	11.45	0.16	0.055	72.25	54.8	30.9

SEWERAGE AND WATER BOARD
New Orleans

TABLE C.2

Investigative Study No. 1

Sample No.	Location	TOC(mg/L)[1]
34	Raw River	10.1/10.5
35	Raw + 5 PAC	2.5/2.4
36	Raw + 50 PAC	1.4/1.5
37	Raw + 500 PAC	0.25/0.20
38	Stirred control	6.0/3.7
39	Unstirred control	3.3/3.2
40	Finish	3.6/3.2
41	Mille-Q control	0.3
42	Mille-Q + 5 PAC	1.9
43	Raw + 5 PAC (Water washed filter)	2.1
44	Raw + 5 PAC (Acid washed filter)	2.3

[1] Duplicate samples were run.

SEWERAGE AND WATER BOARD
New Orleans

TABLE C.3

Volatile Organics (μg/L)(Only Compounds Identified)

Investigative Study No. 1

Sample No.	Location	Chloroform	1, 2-Dichloro-ethane	Benzene	Bromodi-chloromethane	Toluene	Dibromo-chloromethane	Total Inst-THM
34	Raw River	---	1.5	0.25	---	t	–	---
35	Raw + 5 PAC	---	1.1	0.22	---	t	–	---
36	Raw + 50 PAC	---	t	t	---	---	–	---
37	Raw + 500 PAC	t	---	t	---	t	–	---
38	Stirred control	t	1.3	0.35	---	0.24	–	---
39	Unstirred control	t	1.2	0.23	---	0.24	–	---
40	Finish	56.6	1.5	0.38	5.5	t	t	62

SEWERAGE AND WATER BOARD
New Orleans

TABLE C.4

Terminal THM (μg/L)(Only Compounds Identified)

Investigative Study No. 1

Sample No.	Location	Chloroform	Bromodichloromethane	Dibromochloromethane	Total
34	Raw River	184.6	14.5	t	199*
35	Raw + 5 PAC	205.8	21.8	4.2	232
36	Raw + 50 PAC	131.8	20.0	3.4	155
37	Raw + 500 PAC	20.3	11.9	3.8	36
38	Stirred control	201.3	21.7	2.1	225
39	Unstirred control	198.2	20.3	t	219
40	Finish	165.9	16.1	2.5	185

* This value may be less than actual due to insufficient chlorine in the test.

SEWERAGE AND WATER BOARD
New Orleans

TABLE C.5

Specified High Molecular Weight Compounds

Only Compounds Identified (μg/L)

Investigative Study No. 1

Sample No.	Location	Atrazine	Di (2 ethyl hexyl) Phthelate
34	Raw River	0.52	0.58
35	5 mg/L PAC	0.23	1.04
36	50 mg/L PAC	0.24	1.23
37	500 mg/L PAC	0.23	0.47
38	Agitated control	0.25	0.71
39	Unagitated control	0.29	0.58
40	Finish	0.29	0.55

TABLE C.6

Investigative Study No. 1

High Molecular Weight Compounds - Sewerage and Water Board Study (not specified for analysis)

(Concentrations in µg/L)

	*Raw Water	PAC - 5	PAC - 50	PAC - 500	Stirred Control	Unstirred Control	Finish
TOTAL	13.70	22.31	17.93	14.47	18.49	15.06	18.07
N-hexadecane	0.13	0.19	0.26	0.20	0.26	0.25	0.20
Unknown phthalate	0.42	0.35	0.31	0.35	0.40	0.34	0.30
N-heptadecane	0.16	0.08	0.12	0.08	0.08	0.14	0.05
N-octadecane	0.13	0.07	0.05	0 05	0.15	0.03	t
Unknown phthalate	0.11	0.16	0.34	0.17	0.20	0.65	0.10
N-nonadecane	0.16	0.14	0.12	0.12	0.15	0.09	t
Unknown phthalate	0.33	0.65	0.91	0.57	0.66	0.48	0.33
N-eicosane	0.18	0.74	0.16	0.19	**1.04	0.14	**0.37
N-henicosane	0.10	0.08	0.08	0.07	0.08	0.07	0.07
N-docasane	0.14	0.23	0.08	0.06	0.17	0.12	0.16
N-tricosane	0.15	0.16	0.13	0.08	0.09	0.16	0.10
Unknown phthalate	0.31	0.27	0.45	0.27	0.38	0.37	0.22
N-tetracosane	0.24	0.16	0.17	0.13	0.14	0.20	0.14
N-pentacosane	0.21	0.22	0.23	0.08	0.08	0.24	0.11
N-hexacosane	0.17	0.14	0.12	0.07	0.08	0.28	0.10
N-heptacosane	0.14	0.12	0.08	0.05	0.06	0.33	0.08
Squalene	1.92	3.04	0.94	0.46	1.29	0.51	3.81
N-nonacosane	0.18	0.14	0.10	0.13	0.10	0.30	0.09

* Verified by M.S.
** Possible peak contamination.

TABLE C.7

Investigative Study No. 1

THMFP Date – Chlorine Demand

Sample No.	Description	Free Chlorine At Incubation (mg/L)	Final Free Chlorine Residual (mg/L)	Chlorine Demand (mg/L)	Initial Free Chlorine (mg/L)
34	Raw Water	20.00	0.12	19.88	0
35	PAC - 5	20.00	9.67	10.37	0
36	PAC - 50	20.00	12.18	7.82	0
37	PAC - 500	20.00	15.22	4.78	0
38	Stirred control	20.00	9.12	10.88	0
39	Unstirred control	20.00	6.83	13.17	0
40	Finish	20.90	11.98	8.92	0.9
41	Mille-Q stirred	20.00	17.64	2.36	0
42	Mille-Q + 5 PAC	24.00	18.55	5.45	0
43	Raw + PAC - 5 (water washed filter)	20.00	10.97	9.03	0
44	Raw + PAC - 5 (acid washed filter)	20.00	11.15	8.85	0

Sample 34 obviously was not dosed with a sufficient amount of chlorine for the incubation period, leading to low values for formation potential.

APPENDIX D

Investigative Study No. 2 Data

SEWERAGE AND WATER BOARD
New Orleans

TABLE D.1

Investigative Study No. 2 – February, 1979

Sample No.	Description	Temperature °C	pH	Turbidity NTU	UV Absorbance @ 254 nm	UV Scan 190-400 nm	Fluorescence ex 340 nm em 390 nm	Fluorescence scan 370-580 nm
45	Raw River	5	7.57	20.5	0.122	120.8	65.0	42.6
46	Raw & 5 PAC	5	10.49	1.3	1.044	64.7	45.5	27.5
47	Raw & 50 PAC	5	10.50	0.19	0.031	71.3	25.0	15.8
48	Raw & 500 PAC	5	10.42	0.25	0.001	46.8	0.5	0.4
49	Stirred control	5	10.49	0.35	0.045	65.4	54.5	30.7
50	Stirred control chlorination	5	10.50	0.22	0.042	64.8	50.9	29.6
51	Raw & 5 & Cl_2	5	10.48	0.20	0.041	66.0	43.5	27.1
52	Raw & 50 & Cl_2	5	10.42	0.17	0.021	50.6	22.3	12.8
53	Raw & 500 & Cl_2	5	10.38	0.35	0.003	45.0	0.8	0.3
54	Finish	5	10.32	0.62	0.041	78.1	28.6	17.6
55	Unstirred control	5	7.58	12.0	0.102	70.7	54.5	35.9

SEWERAGE AND WATER BOARD
New Orleans

TABLE D.2

Investigative Study No. 2

Sample No.	Location	TOC (mg/L)
45	Raw River	6.6
46	Raw + 5 PAC	3.4
47	Raw + 50 PAC	3.7
48	Raw + 500 PAC	0.6
49	Stirred control	2.3
50	Stirred control chlorinated	2.0
51	Raw + 5 PAC + Cl_2	2.1
52	Raw + 50 PAC + Cl_2	5.5
53	Raw + 500 PAC + Cl_2	0.6
54	Finish	2.3
55	Unstirred control	2.4

SEWERAGE AND WATER BOARD
New Orleans

TABLE D.3

Volatile Organics (µg/L)(Only Compounds Identified)

Investigative Study No. 2

Sample No.	Location	Chloroform	1, 2-Dichloro-ethane	Benzene	Bromodi-chloromethane	Toluene	Dibromo-chloromethane	Total Inst-THM
45	Raw River	---	1.8	t	---	t	t	---
46	Raw + 5 PAC	---	0.66	t	---	t	–	---
47	Raw + 50 PAC	---	t	t	---	t	–	---
48	Raw + 500 PAC	---	---	t	---	t	–	---
49	Stirred control	---	1.2	t	---	0.24	t	---
50	Stirred control chlorinated	17.5	0.93	0.24	t	0.26	–	18
51	Raw + 5 PAC + Cl_2	17.1/17.1*	0.76/0.8*	t	t	0.29/t*	–	17
52	Raw + 50 PAC + Cl_2	10.5/10.0*	t	0.38/0.24*	t	0.41/t*	–	10
53	Raw + 500 PAC + Cl_2	t	t	t	---	t	–	---
54	Finish	36.3	0.79	t	3.1	0.29	t	39
55	Unstirred control	---	0.67	t	---	t	t	---

* Duplicate samples as part of a quality control check.

SEWERAGE AND WATER BOARD
New Orleans

TABLE D.4

Terminal THM (µg/L)(Only Compounds Identified)

Investigative Study No. 2

Sample No.	Location	Chloroform	Bromodichloromethane	Dibromochloromethane	Total
45	Raw River	330.6	18.2	t	349**
46	Raw + 5 PAC	136.9/134.9*	14.1/14.7*	3.6/3.7	154
47	Raw + 50 PAC	108.7/97.1*	17.0/16.6*	7.05/6.3*	126
48	Raw + 500 PAC	16.1/16.0*	8.6/8.7*	6.6/6.0*	31
49	Stirred control	177.8	20.3	6.2	204
50	Stirred control chlorinated	185.5	19.3	5.2	210
51	Raw + 5 PAC + Cl_2	173.9	18.7	7.2	200
52	Raw + 50 PAC + Cl_2	101.5	15.5	6.5	124
53	Raw + 500 PAC + Cl_2	26.9/28.3*	11.5/12.0*	6.9/7.4*	47
54	Finish	139.2	14.8	6.3	160
55	Unstirred control	249.2	21.0	t	270

* Duplicate samples part of a quality control check.
** This value may be less than actual due to insufficient chlorine in the test.

SEWERAGE AND WATER BOARD
New Orleans

TABLE D.5

Specified High Molecular Weight Compounds

Only Compounds Identified (µg/L)

Investigative No. 2

Sample No.	Location	Hexachlorobenzene	Atrazine	Fluorantnene/pyrene	Di (2 ethyl hexyl) Phthalate
45	Raw River	0.12	0.48	t	0.33
46	5 mg/L PAC	—	0.25	—	0.46
47	50 mg/L PAC	—	0.21	—	0.94
48	500 mg/L PAC	—	t	—	0.76
49	Agitated control	—	0.15	—	0.51
50	Agitated control + Cl_2	—	0.26	—	1.42
51	5 + Cl_2	—	0.26	—	1.05
52	50 + Cl_2	—	0.17	—	1.33
53	500 + Cl_2	—	t	—	0.71
54	Finish	—	0.14	—	0.51
55	Unstirred control	—	0.19	—	0.82

TABLE D.6

Investigative Study No. 2

High Molecular Weight Compounds in Sewerage and Water Board Study

(not specified for analysis in Sewerage and Water Board Study)

(concentration in µg/L)

	Raw Water	PAC-5	PAC-50	PAC-500	Stirred Control	Stirred Chlorinated Control	PAC 5 + Cl_2	PAC 50 + Cl_2	PAC 500 + Cl_2	Finish	Unstirred Control
TOTAL	5.52	10.42	17.34	10.68	8.25	15.95	13.39	12.45	9.03	4.32	31.64
2, 6-Di-tert.-butyl-2 methyl phenol (BHT) (tent.)	0.05	0.10	0.15	0.11	0.08	0.11	0.03	t	t	t	0.03
Unknown phthalate	0.30	0.41	0.31	0.27	0.24	0.58	0.60	1.05	0.51	0.27	21.5
Unknown phthalate	0.01	0.26	0.22	0.19	0.18	0.23	0.13	0.21	0.15	0.56	1.04
Unknown phthalate	0.45	0.81	0.78	0.94	0.51	1.16	0.69	1.61	0.81	0.71	2.91
Unknown olefin	0.10	1.61	1.05	2.12	1.84	1.81	3.74	1.48	1.05	0.84	0.36
Unknown olefin	0.02	0.41	0.40	0.29	0.63	1.82	0.46	0.43	0.21	0.03	0.64
Unknown phthalate	0.24	0.40	0.52	0.55	0.31	0.59	0.31	0.01	0.25	0.21	0.75
Unknown phthalate	0.09	0.10	0.18	0.17	0.13	0.40	0.12	0.28	0.10	0.05	0.23
Squalene	0.37	0.76	4.96	1.12	0.67	1.21	0.99	1.61	2.12	0.90	0.47

TABLE D.7

THMFP Data – Chlorine Demand

Investigative Study No. 2

Sample No.	Description	Free Cl_2 Added (mg/L)	Total Amount Free Cl_2 After Dosage (mg/L)	Terminal Free Cl_2 (mg/L)
45	Raw Water	20.00	20.00	0.93
46	PAC - 5	15.00	15.00	5.06
47	PAC - 50	15.00	15.00	9.67
48	PAC - 500	15.00	15.00	11.55
49	Stirred control	15.00	15.00	7.96
50	Stirred chlorinated control	15.00	16.21	10.23
51	PAC - 5 + Cl_2	15.00	16.21	10.51
52	PAC - 50 + Cl_2	15.00	16.41	12.39
53	PAC - 500 + Cl_2	15.00	15.08	11.43
54	Finish	15.00	15.78	9.33
55	Unstirred control	15.00	15.00	9.74

APPENDIX E

Investigative Study No. 3 Data

SEWERAGE AND WATER BOARD
New Orleans

TABLE E.1

Investigative Study No. 3 – February, 1979

Sample No.	Description	Temperature °C	pH	Turbidity NTU	UV Absorbance @ 254 nm	UV Scan 190-400 nm	Fluorescence ex 340 nm em 390 nm	Fluorescence scan 370-580 nm
56	C/S* & 5 PAC	5	10.77	0.28	0.048	83.5	40.7	24.7
57	C/S & 50 PAC	5	10.75	1.3	0.019	55.5	23.5	13.3
58	C/S & 500 PAC	5	10.72	0.20	0.0	46.0	3.2	1.1
59	Stirred control	5	10.83	0.16	0.040	68.7	48.5	28.1
60	Stirred control chlorination	5	10.74	0.80	0.038	68.9	47.5	27.4
61	C/S & 5 PAC & Cl_2	5	10.45	0.20	0.035	64.3	42.5	24.3
62	C/S & 50 PAC & Cl_2	5	10.41	0.16	0.024	63.2	21.0	12.5
63	C/S & 500 PAC & Cl_2	5	10.45	0.17	0.005	48.4	2.4	1.2
64	Unstirred control	5	10.78	0.18	0.043	76.5	46.0	26.7

* C/S = Coagulated/Settled water in feed tanks.

SEWERAGE AND WATER BOARD
New Orleans

TABLE E.2

Investigative Study No. 3

Sample No.	Location	TOC (mg/L)
56	C/S + 5 PAC	1.5
57	C/S + 50 PAC	0.8
58	C/S + 500 PAC	0.1
59	Stirred control	1.6
60	Stirred control chlorinated	1.7
61	C/S + 5 PAC + Cl_2	1.6
62	C/S + 50 PAC + Cl_2	1.0
63	C/S + 500 PAC + Cl_2	0.1
64	Unstirred contrrol	1.5

SEWERAGE AND WATER BOARD
New Orleans

TABLE E.3

Volatile Organics (µg/L)(Only Compounds Identified)

Investigative Study No. 3

Sample No.	Location	Chloroform	1, 2-Dichloro-ethane	Benzene	Bromodi-chloromethane	Toluene	Dibromo-chloromethane	Total Inst-THM
56	C/S + 5 PAC	t	0.62	t	–	t	t	––
57	C/S + 50 PAC	t	t	t	–	t	–	––
58	C/S + 500 PAC	t	–––	t	–	t	–	––
59	Stirred control	t	0.66	t	–	0.26	–	––
60	Stirred control chlorinated	35.9	0.65	0.26	t	0.32	–	36
61	C/S + 5 PAC + Cl_2	29.5	0.57	t	t	t	–	30
62	C/S + 50 PAC + Cl_2	18.8	t	t	t	t	–	19
63	C/S + 500 PAC + Cl_2	t	–––	t	–	t	–	––
64	Unstirred control	t	t	t	–	0.24	t	––

SEWERAGE AND WATER BOARD
New Orleans

TABLE E.4

Terminal THM (µg/L) (Only Compounds Identified)

Investigative Study No. 3

Sample No.	Location	Chloroform	Bromodichloromethane	Dibromochloromethane	Total
56	C/S + 5 PAC	328.3	20.4	5.5	354
57	C/S + 50 PAC	145.7	13.6	6.0	165
58	C/S + 500 PAC	39.6	10.1	7.5	57
59	Stirred control	311.9/317.0*	16.2/18.0*	4.9/5.1*	337
60	Stirred control chlorinated	256.0/254.8*	17.3/17.1*	5.9/5.5*	278
61	C/S + 5 PAC + Cl_2	288.1	20.0	6.8	315
62	C/S + 50 PAC + Cl_2	169.2/167.5*	19.3/17.4*	7.9/7.6*	194
63	C/S + 500 PAC + Cl_2	15.8/18.1*	t/5.4*	t/t*	20**
64	Unstirred control	289.6	17.4	5.7	313

* Duplicate samples as part of a quality control check.
** This value may be less than actual due to insufficient chlorine in the test.

SEWERAGE AND WATER BOARD
New Orleans

TABLE E.5

Specified High Molecular Weight Compounds

Only Compounds Identified (µg/L)

Investigative Study No. 3

Sample No.	Location	Atrazine	Di (2 ethyl hexyl) Phthalate
56	C/S + 5 mg/L PAC	0.16	0.46
57	C/S + 50 mg/L PAC	0.28	0.55
58	C/S + 500 mg/L PAC	0.22	0.49
59	Agitated control	0.44	0.43
60	Agitated control + Cl_2	0.42	0.47
61	5 + Cl_2	0.17	0.31
62	50 + Cl_2	0.20	0.36
63	500 + Cl_2	0.18	0.49
64	Unstirred control	0.25	0.35

TABLE E.6

High Molecular Weight Compounds in Sewerage and Water Board Study (not specified for analysis)

(concentration in µg/L)

Investigative Study No. 3

	C/S + PAC - 5 *	C/S + PAC - 50	C/S + PAC - 500	Stirred Control *	Stirred Chlorinated Control *	PAC - 5 + Cl_2 *	PAC - 50 + Cl_2	PAC - 500 + Cl_2	Unstirred Control
TOTAL	17.22	21.68	16.76	11.93	17.05	13.03	11.85	12.77	10.22
Unknown phthalate	0.46	0.23	0.20	0.28	0.26	0.22	0.26	0.36	0.24
N-heptadecane	0.07	0.08	0.06	0.05	0.06	0.03	0.07	0.07	0.09
N-octadecane	0.06	0.05	0.04	0.06	0.07	0.09	0.03	0.03	0.09
Unknown phthalate	0.10	0.04	0.05	0.10	0.06	0.05	0.15	0.08	0.06
N-nonadecane	0.06	0.16	0.12	0.07	0.10	0.08	0.11	0.11	0.08
Unknown phthalate	0.66	0.51	0.45	0.45	0.37	0.36	0.56	0.63	0.38
Olefin (tent.)	1.68	4.04	2.30	1.07	1.97	2.79	2.15	2.29	1.24
N-docosane	0.62	0.08	0.04	0.06	0.22	0.23	0.10	0.04	0.04
Unknown phthalate	0.21	0.22	0.09	0.08	0.42	0.41	0.10	0.08	0.06
N-tricosane	0.12	0.35	0.10	0.12	0.13	0.10	0.10	0.11	0.12
Unknown phthalate	0.22	0.29	0.22	0.19	0.29	0.22	0.22	0.30	0.26
N-tetracosane	0.12	0.38	0.11	0.11	0.11	0.13	0.13	0.15	0.14
N-pentacosane	0.12	0.32	0.08	0.07	0.10	0.12	0.12	0.11	0.11
N-hexacosane	0.11	0.39	0.11	0.14	0.12	0.12	0.09	0.08	0.10
N-heptacosane	0.09	0.27	0.03	0.04	0.05	0.08	0.05	0.06	0.06
N-octacosane	0.14	0.22	0.04	0.06	0.05	0.10	0.07	0.06	0.07
Squalene	2.93	1.02	0.95	0.55	0.63	0.36	0.29	0.33	0.42
N-nonacosane	0.13	0.20	0.04	0.04	0.05	0.07	0.04	0.05	0.05

* Verified by M.S.

TABLE E.7

THMFP Data – Chlorine Demand

Investigative Study No. 3

Sample No.	Description	Free Cl_2 Added (mg/L)	Total Amount Free Cl_2 After Dosage (mg/L)	Terminal Free Cl_2 (mg/L)
56	C/S + PAC - 5	15.00	15.00	13.56
57	C/S + PAC - 50	15.00	15.00	8.91
58	C/S + PAC - 500	15.00	15.00	10.89
59	Stirred control	15.00	15.00	7.63
60	Stirred control chlorinated	15.00	16.81	10.13
61	PAC - 5 + Cl_2	15.00	16.75	10.07
62	PAC - 50 + Cl_2	15.00	16.67	9.66
63	PAC - 500 + Cl_2	15.00	15.79	0.10
64	Unstirred control	15.00	15.00	7.36

Inadvertently Sample No. 63 may not have been dosed with 15 ppm chlorine at the time of THMFP preparation. When this was discovered at the end of the THMFP period, the remaining amount of Sample No. 63 which had been stored in the refrigerator was dosed with 15 ppm chlorine, incubated, and at the end of the period had 15 ppm chlorine residual. This sample was resubmitted to UNO as 63B for VOA Terminal analysis.

APPENDIX F

Carbon Data

nuchar®
powdered activated carbons

Aqua Nuchar®

Description and Typical Applications

Aqua Nuchar is a high quality, powdered activated carbon specifically designed for the treatment of potable water. It is the result of more than sixty years' experience in the manufacture of activated carbons and fifty years' service to water treatment utilities. The high iodine number is indicative of the large surface area available for the adsorption of undesirable organic substances, including those that produce tastes and odors. The particle size and density have been balanced to insure adequate contact, while minimizing carry-over to the filters. For the production of a palatable water at a cost-effective price, specify *Aqua Nuchar*.

Carbon Properties

Iodine Number (mg/g)	800 ± 100
A.W.W.A. Phenol Value (g/l)	2.0 ± 0.25
Modified Phenol Value (mg/l)	16.0 ± 2
Moisture, As Packed (%)	3 ± 2
Apparent Density (lb/cu ft)	36 ± 4
(kg/cu m)	577 ± 64
Sieve Analysis:	
Thru 100 mesh (%)	99-100
Thru 200 mesh (%)	97-99
Thru 325 mesh (%)	92-98

Aqua Nuchar exceeds A.W.W.A. specifications B-600-78.

Packaging

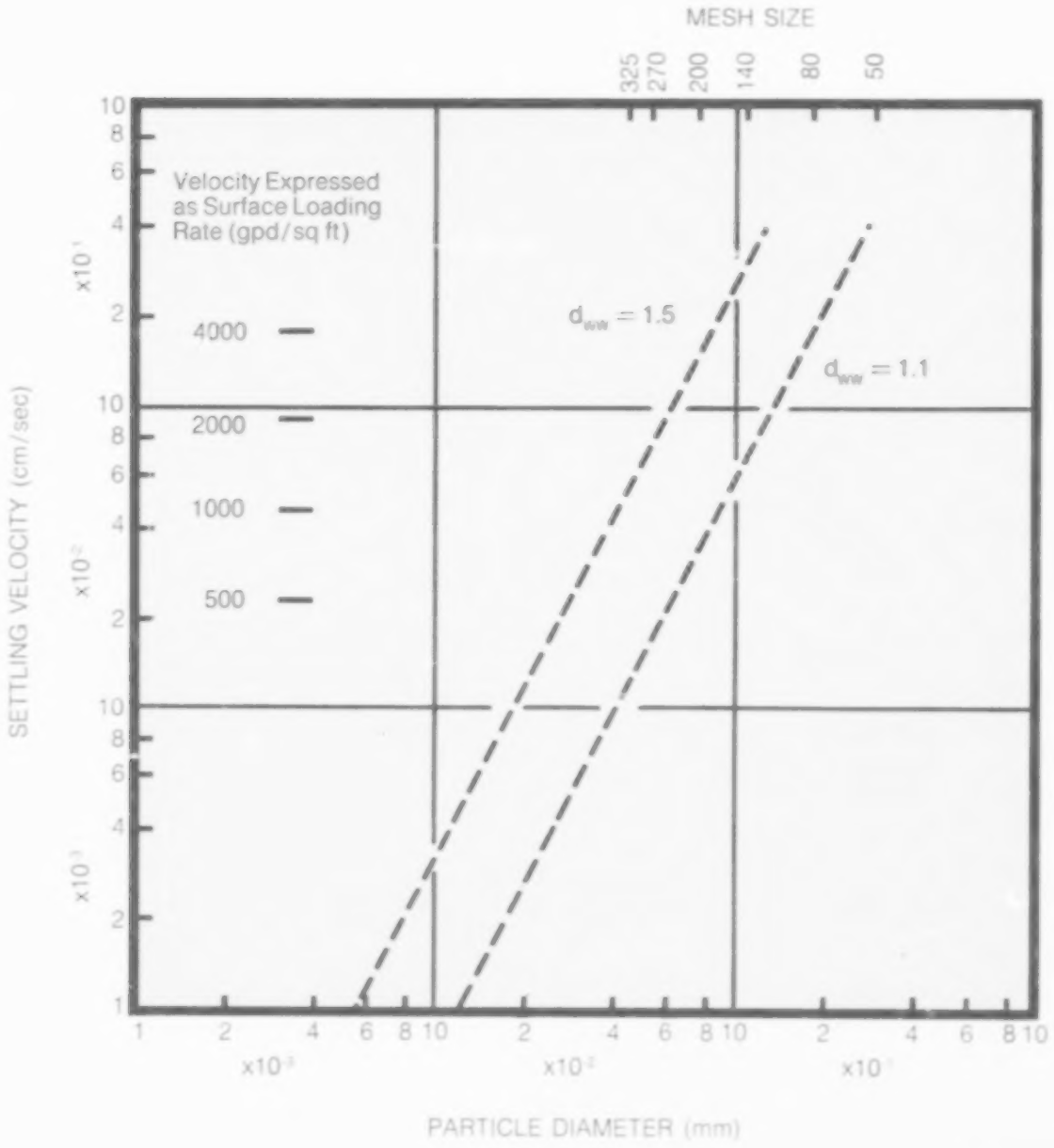
Aqua Nuchar is available in bulk trucks, bulk rail cars or in individually shrink-wrapped 65 pound multiwall paper bags on non-returnable, wood pallets.

Westvāco
Chemical Division
Carbon Department
Covington, Virginia 24426
(703) 962-1121

9/78 Supercedes all previous *Aqua Nuchar* Data Bulletins.

Settling velocities as a function of particle diameter and density wetted in water

The settling velocities of powdered activated carbons are shown below as a function of particle size and density wetted in water (d_{ww}) at 25° C. It is apparent from this curve that size is the overriding factor. The new *Aqua Nuchar* has a mean particle diameter of 8-9 microns and a density wetted in water of 1.4 to 1.5. The average settling velocity is very close to the settling velocity of the previous *Aqua Nuchar* product which had a mean particle diameter of 10-11 microns and a density wetted in water of 1.15 to 1.20.



Amoco®
active carbon

Background

Amoco® active carbon is a new form of active carbon having an exceptionally high surface area and adsorptive capacity. It has been under development for over a decade. Our pilot plant recently started production on several grades for experimental testing.

Technical Information Sheets

The accompanying technical data represents the various grades of Amoco® active carbon currently available. Developmental work is also in progress on granular carbons suitable for liquid phase contact that can be thermally regenerated.

Samples

In an effort to verify the increased efficiency of Amoco® active carbon, we are offering, free of charge, lab size samples for comparative analysis and experimental testing. In return, we would appreciate receiving your appraisal and the results of your testing. Such information would be kept strictly confidential and would be used for project development purposes only. Disclosure to third parties would require your written approval.

Commercial Production

A commercialization decision has not yet been reached. The results obtained from extensive field testing will allow an assessment of the commercial potential for these new forms of active carbon.

Your interest in our active carbon project is very much appreciated. We would be happy to discuss further details and answer any questions you may have following your review of the enclosed material.

Amoco Research Corporation · P.O. Box 5910 · A · Chicago, Illinois 60680 · (312) 856 · 2474

AMOCO ACTIVE CARBON
LOT ANALYTICAL SHEET

LOT NO. 76-17

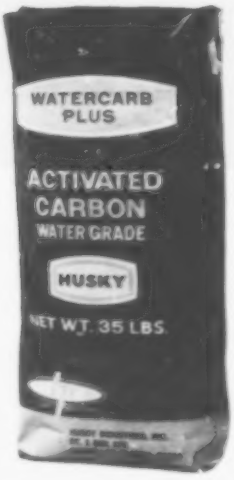
SOCo BET Surface Area, m^2/gm	2273
Total Organic Carbon Index (TOCI)	MSD-155, 211-MSD, 258-W, 232-N
Iodine No.	2388
Phenol No.	(OLD) 9.6 (New) 1.065
Methylene Blue Adsorption, mg/gm	400
Molasses No.	25
Digisorb BET Surface Area	1772
Pore Distribution, Radius Angstrom	Pore Vol.>15Å = 0.0473, Pore Vol.<15Å = 0.848
Average Pore Size, Radius Angstrom	26.9
Cumulative Pore Volume, cc/gm	0.0473
Bulk Density, cc/gm	0.491 cc/gm
Particle Size	
Passes 100 mesh, wt%	99.4, 98.4
Passes 200 mesh, wt%	91.8, 91.2
Passes 325 mesh, wt%	78.9
Ash, wt%	1.52
Water Solubles, wt%	1.00%
pH of Carbon	6.0
CCL_4 Activity	117.47
CCL_4 Retentivity	91.27
Butane Wrg. Capacity =	0.0% Wt - 0.0% Vol

Notes PY-24

Bulletin No. 783

WATERCARB PLUS ACTIVATED CARBON

WATERCARB PLUS POWDERED ACTIVATED CARBON



Weight, 35 lbs.

Meets A.W.W.A. B-600-78, Sec. 3.2, Sec. 3.3, Sec. 3.2.1, available

Bag size, 20" x 33"

Bag construction: 4 ply. 3-40; P.E. FILM; 1-50

Bulk in rail cars or trucks

Husky Powdered Activated Carbon meets A.W.W.A. specifications B-600-78 for treatment of potable drinking water. A representative sales specification shown below:

Modified Phenol Value (ppm)	16 ± 2
Modified Phenol Value (g/1)	1.59 - 2.05
Density, #/cu. ft.	28 - 32
Dispersion	220 - 240
Suspendability, %	75 - 80%
Iodine Number, Min.	650
Iodine Value, Min.	90
Moisture, % Max. (When shipped)	5%
Total Ash, % Max.	7%
Acid Insoluble Ash, % Max.	1.5%
Fineness, U. S. Sieve Series	
Thru 100 Mesh, % Min.	99%
Thru 200 Mesh, % Min.	97%
Thru 325 Mesh, % Min.	90%

Husky Activated Carbon, "Watercarb Plus" available from Romeo, Florida. Shipped in 35 lb. bags either loose, on pallets, in boxes on pallets, or in slipover bags. Also shipped in railcars and company owned and operated trucks. Husky Activated Carbon is totally compatible with all municipal water treatment use and application systems.

HUSKY INDUSTRIES

INDUSTRIAL DIVISION
Route 1, Box 275 Dunnellon, Florida 32630
Phone: 904-489-3336

ICI Americas Inc.

HYDRODARCO® B POWDERED ACTIVATED CARBON FOR TREATMENT OF MUNICIPAL WATER SUPPLIES

HYDRODARCO B is a specialty activated carbon with a high capacity for adsorption of organics causing tastes and odor problems in water supplies.

GENERAL CHARACTERISTICS

HYDRODARCO B is finely ground to obtian a high degree of suspendability in water for more efficient removal of tastes and odors.

The raw material used for HYDRODARCO B is lignite, which is highly activated by heat and steam under closely controlled conditions.

PROPERTIES (TYPICAL VALUES)

Moisture Content (as packed)	8%
Water - Solubles (4 leachings with boiling water)	3-5%
pH	Alkaline
Bulk Density, lbs./ft.^{3} (30-minute tamping test)	25-35
Mesh Size, through 325 mesh screen, Min.	95%

SPECIFICATIONS

Phenol Value*	<30

*The American Water Works Association specifies a phenol value of 30 or below, i.e., 30 ppm carbon required to reduce phenol concentration from 0.10 ppm to 0.01 ppm. ICI Americas suggests that the phenol test should not be over emphasized because most municipal water contaminants are not phenolic compounds. The carbon should be evaluated for removal of undesirable tastes and odors which occur in the water supplies to be treated.

PACKING AND SHIPPING

HYDRODARCO B is packed in 3-ply bags, net weight 50 lbs. For less-than-truckload shipments from warehouses, bags are enclosed in fiber cartons. For carload or truckload shipments from our Marshall, Texas, plant, bag-packing only is used, unless carton-packaging is specified at slightly higher price. Each package occupies about 2 cubic feet.

Shipments are also made in bulk cars or bulk trucks, on request.

FOR YOUR PROTECTION

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